JUL 22 1924

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VOL. CXVIII.—No. 3054.] *LONDON: FRIDAY, JULY 11, 1924.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 4d.

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Steam & Crude Oil Road Rollers, &c.
1869

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CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See advertisement page 10.
PATENT WATER-TUBE BOILERS.
AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 2179

Dredging Plant
OF ALL DESCRIPTIONS.
FLOATING CRANES. COAL BUNKERING VESSELS.
Werf Conrad, HAARLEM, HOLLAND.
Agents: MARINE WORKS, LTD., FRIARS HOUSE, 39-41, NEW BROAD ST., LONDON, E.C.2.
See half-page Advert. last week and next week. 2087

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STEEL TANKS, PIPES, GASHOLDERS, &c.
Thos. Piggott & Co., Limited,
BIRMINGHAM. 1241
See Advertisement last week, page 19.

Spencer-Hopwood & Kirke
PATENT BOILERS *See Page 71.* 1994
Sole Makers: SPENCER-BONECOURT, LTD., Parliament Mansions, Victoria St., London, S.W.

Tank Locomotives.
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO. LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 1864

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MANUFACTURERS OF RAILWAY CARRIAGES AND WAGONS OF EVERY DESCRIPTION.
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Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 2257
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HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement, pages 35 and 65, July 4.

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PASSENGER AND CARGO STEAMERS.
SHALLOW DRAFT VESSELS. 2276

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Worm Wheels cut up to 13 ft. diam.
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PORTSMOUTH,
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Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS, and EVERY OTHER DESCRIPTION OF RAILWAY and TRAMWAY ROLLING STOCK.
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Systems
PRESSURE, AIR, STEAM
For Boilers of all types.
KERMODES LIMITED,
35, The Temple, Dale Street, Liverpool.
Naval Outfits a Speciality,
also for Merchant Ships, for Factories, Locomotives, and Industrial Process Furnaces of all kinds.
Supplied to the British and other Governments.
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Telegrams: "Warmth." 4078

Locomotives Tank Engines
designed and constructed by
MANNING, WARDLE AND COMPANY, LIMITED,
Boyne Engine Works, Leeds. Oct 2487
See their Illus. Advertisement, page 93, last week.

Gearing of all Descriptions.
GEAR WHEELS up to 10 ft. diameter.
FLY ROPE and SPUR DRIVING WHEELS up to 28 ft. diameter.
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BUILDERS of RAILWAY CARRIAGES & WAGONS
MAKERS of WHEEL and AXLES of all kinds
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London Office: Od 8353
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S. H. HEYWOOD & CO., LTD., 1357
REDDISH.

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CELITE PRODUCTS CORPORATION, Windsor House, Westminster, S.W.1. 1675
See our Illustrated Advertisement, July 4.

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Gas Engines Inspected, Tested and Reported upon. Over 25 years' experience. Tel.: Maryland 1736 & 1737. Wire: "Rapidising, London."—Great Eastern Road, Stratford, E.15. 1794

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MECHANICAL ENGINEERS,
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Undertake SPECIAL MACHINE WORK of any description.
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GENERAL CONSTRUCTIONAL ENGINEERS,
Boilers, Tanks, & Mooring Buoys
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Tubes AND Fittings AND Steel Plates.
STEWARTS AND LLOYDS, Ltd.
GLASGOW BIRMINGHAM - LONDON.
See Advertisement, page 41. 1872

Peter Brotherhood Ltd.,
PETERBOROUGH.
STEAM ENGINES AND TURBINES.
GAS AND OIL ENGINES.
AIR COMPRESSORS.
REFRIGERATING PLANT. 1473
See Advertisement, page 55, July 4.

Patents.—Exhibition Visitors
can obtain information respecting patents, etc., from B. T. KING, Regd. Patent Agent, 146A, Queen Victoria St., E.C.4. For free appointment Wembley Exhibition, 'Phone Central 682. Handbook free.

For Your Repairs or any
SPECIAL MACHINERY, try
THOMAS HUNT & SONS,
Albion Ironworks,
Bridge Road West, Battersea, S.W. 11.
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Important.—For Immediate
SALE AT LOW PRICES.
One Superior 400 Kw. Howden-Siemens ELECTRIC GENERATING SET, 260 volts D.C., 350 r.p.m., 155 lbs. pressure.
One High-Class Horizontal Side-by-Side COMPOUND CORLISS ENGINE, 200 I.H.P. at 80 r.p.m., belt flywheel 12 ft. diameter by 2 ft. 6 in. on face, very suitable for export, for driving factory, sawmill, etc.
One Powerful Set COMPOUND HORIZONTAL HYDRAULIC PUMPING ENGINES, by Sir Wm. Arrol & Co., capacity 200 gallons per minute.
Two Steamdriven CENTRIFUGAL PUMPS, by Drysdale, capacity 1250 and 1390 gallons per minute.
In new condition and all seen here at Glasgow.
JOHN H. RIDDELL LTD.,
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Gears.
Spurs, Bevels.
Spiral, Worm and Worm Wheels.
HIGHFIELD GEAR CUTTING CO. (Dept. R.), Huddersfield. 1645

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BRITISH and FOREIGN. Moderate charges. Long and varied practical Engineering experience valuable to Inventors. Formerly many years contributor of Patents Abstracts for "The Engineer" & "The Times."—Thanet House, Temple Bar, London, W.C.2.

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Telephone: 7494 Central.
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CHARTERED PATENT AGENTS,
306, High Holborn, London, W.C. 1. 585
PATENTS. DESIGNS. TRADE MARKS.

The Examination of the
Interior of Hollow Forgings with "Davon" Pat. Micro-telescope. See Metropolitan Vickers Co., Exhibit, Wembley.—F. DAVIDSON & CO., 29, Great Portland St., London, W.1. 2114

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS EVAPORATORS, CONDENSERS, AIR HEATERS, } ROWS PATENTS,
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SYPHONIA STEAM TRAPS, REDUCING VALVES.
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 5723

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LAND AND MARINE
YARROW BOILERS. 2277

Matthew Paul & Co., Ltd.,
LEVENFORD WORKS, Dumbarton. 2212
See Full Page Advt., page 56, June 20.

Forgings.
Walter Somers, Limited,
HALESOWEN. 7116

Taylor & Challen Presses
For Production of SHEET METAL WORK, COINAGE, CARTRIDGES AND GUNPOWDER.
Foundry, Works and Showrooms: BIRMINGHAM.
See Advert., page 96, June 20. 8196

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 58. 3402

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED, DARLINGTON. 2006

RAILWAY AND TRAMWAY ROLLING STOCK.
Hurst, Nelson & Co., Ltd.,
THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3383

The Glasgow Railway Engineering Company,
GOVAN, GLASGOW. LTD.,
London Office—12, Victoria Street, S.W.
MANUFACTURERS OF RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 1948

Locomotive Traversers
(ELECTRIC). 1357
S. H. HEYWOOD & CO., LTD., REDDISH.

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WORKS: 1933
BURNT MILL, ESSEX.
We are organised to produce castings from 2 lbs. to 2 tons. Cast-iron, Semi-steel, and Non-ferrous castings. Coils of every description, Steel and Copper. Sheet Metal Work. Over 40 years' experience is at your service. Send your enquiries along.

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND.
1475
See half-page Advertisement, page 66, July 4.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.

Chief Engineer: C. E. STROMEYER, M.I.C.E.

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Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 2005

University College of Swansea.

(A Constituent College of the University of Wales).

APPLIED SCIENCE DEPARTMENTS.

ENGINEERING.

Professor: FREDERIC BACON, M.A. (Cantab.), A.M.Inst.C.E., M.I.Mech.E., M.I.E.E.

Lecturer in Electrical Engineering: R. G. ISAACS, M.Sc. (Bristol), B.Sc. (Lond.), A.M.I.E.E.

Lecturer in Civil Engineering: H. H. BURVESS, M.O., B.Sc. (St. Andrews), A.M.Inst.C.E., A.M.I.Mech.E.

Assistant Lecturer: J. SELWYN CASWELL.

METALLURGY.

Professor: C. A. EDWARDS, D.Sc. (Manchester).

Lecturer: A. L. NORBURY, M.Sc. (Manchester).

Assistant Lecturers: L. B. PFEIL, B.Sc. (Lond.), A.R.S.M., P. M. MACNAIR, B.Sc. (Glasgow).

The College offers a number of exceptional advantages to Students who aim at entering upon professional careers in Engineering or in Metallurgy. It is situated in the heart of an industrial area, which includes a large number of works of very varied character, and presents an unrivalled variety of metallurgical practice. The manufacturers of the district, who contribute largely to the support of the College, give the Staff and Students of the Applied Science Departments every access to the Works, and the Managers, Engineers, and Technical Officials co-operate with the Staff of the College in making visits to works of practical educational value to the students.

Courses of study are provided (1) for the B.Sc. degree of the University of Wales in (a) Civil Engineering; (b) Mechanical Engineering; (c) Electrical Engineering; (d) Metallurgy, and (2) for Diplomas of the College in (a) Civil Engineering; (b) Mechanical Engineering; (c) Electrical Engineering; (d) Metallurgy.

Persons who are not desirous of studying for Degrees or Diplomas may attend selected College Classes, provided they satisfy the authorities of the College that they are qualified to benefit by such classes.

Entrance Scholarships will be offered for competition in September, 1924.

Particulars concerning admission to the College, and of the Entrance Scholarships, may be obtained from the undersigned.

EDWIN DREW,
Registrar.

Singleton Park,
Swansea. F 263

Correspondence Courses for Inst.C.E., Inst.Mech.E., London Univ. (Matric., Inter., B.Sc.), and All ENGINEERING EXAMINATIONS personally conducted by Mr. TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., etc. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 8/11, TRAFFORD CHAMBERS, 58, SOUTH JOHN STREET, LIVERPOOL. 1993

Engineering Salesmanship and SALES MANAGEMENT.—Write for brochure describing our special Course of Training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 2282

Engineering Drawing.—

Enrol now for Special Postal Course in Engineering Drawing. Fee Three Guineas for the complete course. Also private coaching for Engineering examinations by qualified teacher (M.I.Mech.E.).—Call or write; THE VORTEX COMPANY, 25, Victoria Street, London, S.W.1. 2297

TENDERS.

COUNTY COUNCIL OF SUTHERLAND.

STEAM ROLLER, &c.

Tenders are Invited for a

10 Ton (Nominal) STEAM ROAD ROLLER with Scarifier (3 tine); One WATER CART (200 Gallon); and One SLEEPING VAN (3 Berths).

Sealed Tenders, with detailed Specification, to be lodged with the Undersigned on or before 31st July, 1924, and stating when delivery could be made.

ARCHD. ARGO,
County Clerk.

County Clerk's Office,
Golspie.
7th July, 1924. F 308

COMMISSIONERS OF IRISH LIGHTS.

NOTICE TO SHIPBUILDERS.

The COMMISSIONERS OF IRISH LIGHTS are prepared to receive

Tenders for the Construction

of a STEEL (or, alternatively STEEL and IRON) LIGHTSHIP.

Principal Dimensions:—

102 ft. by 24 ft. 3 ins. moulded, and 13 ft. 6 in. depth of Hold.

Firms who will undertake to submit a *bona fide* quotation for this work may obtain Drawings, Specifications and Form of Tender on application to the undersigned.

Tenders, sealed and endorsed "TENDER FOR LIGHTSHIP" must be posted so as to reach the Secretary's Office, Carlisle Buildings, D'Olier Street, Dublin, on or before Thursday, the 14th day of August, 1924.

The Commissioners do not bind themselves to accept the lowest or any Tender.

By Order,
J. B. PHELPS, Secretary.

Irish Lights Office,
Dublin, 7th July, 1924. F 282

BENGAL-NAGPUR RAILWAY COMPANY LIMITED.

The Directors are prepared to receive

Tenders for:—

OPEN AND COVERED GOODS WAGONS AND BRAKE VAN UNDERFRAMES.

Specifications and Forms of Tender can be obtained at the Company's Offices, 132, Gresham House, Old Broad Street, E.C.2, on or after 8th July, 1924.

A fee of 20s. will be charged for the Specification, which is NOT returnable.

Tenders must be submitted not later than Noon on Tuesday, 22nd July, 1924.

The Directors do not bind themselves to accept the lowest or any Tender, and reserve to themselves the right of reducing or dividing the order.

By Order of the Board,
R. C. VOLKER,
Secretary. F 298

ELECTRICALLY DRIVEN PUMP.

ONE—Two stage Centrifugal Pump, 12 in. suction and delivery, capable of discharging 3500 gallons of water per minute against a head of 165 ft. 0 in.

The Pump is mounted on same bedplate with, and direct coupled to —

ONE—230 B H P. 440 volt, three phase, 50 cycles, Slip Ring induction Motor.

A Motor starter and oil immersed controller is provided.

The whole set is made by Messrs. Mather and Platt of Manchester.

Overall dimensions 13 ft. long by 3 ft. 6 in. wide by 4 ft. 6 in. high.

The following fittings are included:—

One Vacuum gauge, one pressure gauge, one 12 in. suction bend, foot valve, and strainer, and a certain length of delivery pipe.

Offers for the Purchase of

this PLANT are Invited by GEORGE COHEN & ARMSTRONG DISPOSAL CORPORATION, Abbey House, 2, Victoria Street, S.W.1.

Telephone Victoria 8040. F 274
Telegrams "Cohstrong Sowest."

From whom permits to view can be obtained.

LONDON AND NORTH EASTERN RAILWAY.

TO BUILDERS AND IRONFOUNDERS.

The Directors are prepared to receive

Tenders for New Roofing

over Platforms and ALTERATION to STATION BUILDINGS, at Ashington.

Plans and specification may be seen and Quantities and further information obtained upon application to Mr. STEPHEN WILKINSON, Architect, N.E. Area, L. & N. E. Rly., at Irving House, Westgate Road, Newcastle-on-Tyne, on and after 7th July.

Quantities supplied to parties Tendering for the whole of the works.

Sealed Tenders, marked "Ashington Station Roofing, &c.," to be sent to the Joint Secretaries at Marylebone Station, London, N.W. 1, by not later than Nine a.m. on 21st July.

The Directors do not bind themselves to accept the lowest or any Tender.

JAMES McLAREN,
G. F. THURSTON,
Joint Secretaries.

Secretary's Office,
L.N.E. Railway,
Marylebone Station,
2nd July, 1924. F 270

IN THE HIGH COURT OF JUSTICE (Companies Winding Up).

To be Offered For Sale by

TENDER, pursuant to a Order of the Registrar Companies (Winding Up) made in the matter of ALLEN & SIMMONDS (READING), LTD., Branch Nominees Ltd., *v.* Allen & Simmonds (Reading), Ltd., 1923, A. No. 2686, either in One Lot as a Going Concern, or in the following Lots:—

LOT 1.

(A) A FREEHOLD GARAGE, SHOWROOMS AND OFFICES situate in the centre of READING, with frontages to Friar Street and Station Road, and containing an area of about 23,000 square feet, together with the Assets and the Business carried on on such premises, and the whole of the Share Capital and Debentures in Great Western Motors Ltd.

(B) A block of TEN FREEHOLD COTTAGES adjoining the above.

(C) A FREEHOLD FACTORY at Vastern Road, READING, with Modern Buildings thereon, covering an area of about 14,500 square feet, at present let as a Motor Body Building Works, in connection with the aforesaid business.

LOT 2.

(A) A LEASEHOLD ENGINEERING WORKS, at READING containing a total floor space of about, 27,000 square feet, held for an unexpired term of 67 years at Ground Rents amounting to £77 6s. per annum. These Works are equipped with high-class ENGINEERS' MACHINE TOOLS for the manufacture of Piston Rings and other Specialities of the Company.

(B) THIRTY LEASEHOLD COTTAGES and a RESIDENCE adjoining held for a similar period at nominal ground rents.

(C) LEASEHOLD PREMISES suitable for GARAGES, situate No. 107, Caversham Road, READING, held for an unexpired term of 61 years.

(D) A FREEHOLD PROPERTY on the THAMES, at CAVERSHAM, adjoining the Bridge, formerly a Club, but now let off in self-contained Flats.

(E) A FREEHOLD HOUSE, No. 18, King's Meadow Road, READING.

(F) THE GOODWILL OF THE BUSINESS of ALLEN & SIMMONDS (READING), LTD., as a Going Concern, and LETTERS PATENT for Improvements in the manufacture of Piston Rings, etc.

LOT 3.

3,000 £1 fully-paid Shares, Great Western Hotel (Reading), Ltd.

25 £1 fully-paid Deferred Ordinary Shares, and 5,500 £1 fully-paid Participating Preferred Ordinary Shares in the Reading Foundry Co., Ltd.

Tenders, which must be on the form contained in the Particulars, are to be sent to the Registrar, Companies (Winding Up), Room 48, Bankruptcy Buildings, Carey Street, W.C.1, and marked "Tenders re Allen & Simmonds (Reading), Ltd.," and delivered under seal by TWELVE NOON, on or before SATURDAY, 19th July, 1924. Particulars, with Plan, Form of Tender and Conditions of Sale, may be had of Messrs. W. B. PEAT & CO., Chartered Accountants, 11, Ironmonger Lane, London, E.C.2, Messrs. WILDE, WIGSTON & SAPTE, Solicitors, 21, College Hill, London, E.C.4; and of Messrs. PEACOCK & GODDARD, of 3, South Square, Gray's Inn, London, W.C.1. F 33

The Director-General,

India Store Department, Branch No. 16, Belvedere Road, Lambeth, S.E. 1, REQUIRES:—

1. WHEELS, chilled cast iron.
2. UNIVERSAL COUPLINGS for vacuum brakes.

Tenders due on the 22nd July, 1924.
Tender forms obtainable from above. F 313

SIAM STATE RAILWAYS.

NOTICE.

Tenders are Invited for the

SUPPLY of ALL STEEL GOODS WAGONS. Specifications and Drawings may be obtained against payment of £1 10s. (not returnable) from Messrs. C. P. SANDBERG, 40, Grosvenor Gardens, London, S.W. 1.

Sealed Tenders, with the inscription "Tender for the Supply of All Steel Goods Wagons, B.E. 2467," must be forwarded to the undersigned, at whose office in Bangkok, Siam, they will be received up to Fourteen o'clock on the 31st October, 1924, at which place and hour the Tenders will be publicly opened and read.

Right is reserved to reject any or all Tenders, and to accept any Tender which in the opinion of the undersigned is to the best interests of the Siam State Railways.

Department of State Railways,
BANGKOK. F 310
(Sgd.) ACTING COMMISSIONER GENERAL.

GREAT NORTHERN RAILWAY (IRELAND).

TO BRIDGE CONTRACTORS.

The Directors are prepared to receive

Tenders for the Reconstruction

of a STEEL UNDERLINE BRIDGE, between Knockmore Junction and Hillsborough.

The Drawings and Specification may be inspected at the Engineer's Offices, Dublin and Belfast, and copies of same, together with Bills of Quantities and Forms of Tender, may be obtained from the undersigned, on payment of Two Guineas, which will be refunded on receipt of a *bona fide* Tender, and on return of the Drawings.

Tenders made out on the Forms supplied by the Company should be delivered, under sealed cover endorsed "TENDER FOR BRIDGEWORK," not later than Ten a.m. on Monday, 21st July.

The Directors do not bind themselves to accept the lowest or any Tender.

J. B. STEPHENS,
Secretary.

Amiens Street Station,
Dublin, 8th July, 1924. F 315

G. R.

BY DIRECTION OF THE SURPLUS STORES, ETC., LIQUIDATION DEPARTMENT, H.M. TREASURY.

The Department invites

Tenders for the Purchase of

the COMPONENT PARTS of about 4,000 FREIGHT CARS of Russian Railway Gauge, lying in Canada (approximately 43,000 tons).

The components are offered for export only in one lot as they lie.

Sale conditions and particulars, together with Form of Tender, can be obtained from the SECRETARY, Treasury Surplus Stores, &c., Liquidation Department, Caxton House, Tothill Street, Westminster, London, S.W. 1, or from Mr. J. H. FRANCIS, 65, Broadway, 10th Floor, New York City. Mr. Francis will supply the necessary Permits to inspect the material.

Sealed Tenders, in the envelopes supplied, should be sent direct to the

SECRETARY,
TREASURY SURPLUS STORES, ETC.,
LIQUIDATION DEPARTMENT,

so as to be received not later than 20th August, 1924. F 280

APPOINTMENTS OPEN.

COUNTY OF SURREY.

HIGHWAYS AND BRIDGES DEPARTMENT.

RUINS BRIDGE RE-CONSTRUCTION.

Applications are Invited for

the APPOINTMENT of CLERK OF WORKS to act under the directions of the County Surveyor to take charge of the works comprised in the Reconstruction of Ruins Bridge, Virginia Water, which is being done under Contract. Salary at the rate of £6 per week.

Applications in writing stating full particulars of appointments held and experience on bridge and reinforced concrete works, accompanied by references, should reach the undersigned not later than Friday, the 18th of July, 1924.

Forms of application and further particulars may be obtained from the undersigned. Stamped addressed envelope should be forwarded.

W. P. ROBINSON, A.M.Inst.C.E.,
County Surveyor.

County Hall,
Kingston-on-Thames.
7th July, 1924. F 285

A Works Manager is Required

by Progressive Firm of Engineers, making precision parts and assemblies. Good opportunity for a live energetic man.—Address, stating age, experience and salary required, F 267, Offices of ENGINEERING.

Works Manager Required

by Progressive Firm of Engineers, making precision parts and assemblies. Good opportunity for a live energetic man.—Address, stating age, experience and salary required, F 267, Offices of ENGINEERING.

Wanted, by Well-known

Engineers in the North, WORKS MANAGER. Knowledge of gearing essential. State qualifications and salary required.—Address, F 306, Offices of ENGINEERING.

Wanted, Manager, by Old-

established Marine Engineering and Ship Repairing Firm; must have Drawing Office experience, and a good knowledge of workshop practice and ship and machinery repairs. A good opening for a first-class man.—Address, stating age, experience and salary required, AMOS AND SMITH LTD., Hull. F 303

India.—Wanted, First-class

MAN as Manager of Railway Wagon Department of Important Engineering Firm. Excellent opportunity for thoroughly capable man.—Write, stating age, with full particulars of training and experience, and copies of testimonials, to Z.H. 940, c/o DEACONS, Leadenhall Street, London, E.C. 3. F 297

Machine Tool Salesman as

Assistant. Experience in other Mechanical Engineering lines an advantage, but a sound Machine Tool experience is essential. Salary, £300-£400.—Write, BOX 562, DORLAND AGENCY, 14, Regent Street, S.W.1. F 272

Young Man Wanted, Capable

of being trained as buyer for a machinery dealing firm. Some knowledge of machinery, honesty, common sense, confidence, responsibility and 'savvy' essential. Send full particulars.—Address, F 308, Offices of ENGINEERING.

Wanted, for a Proposed Fuel

Economy Bureau, a GENTLEMAN with an intimate theoretical and practical knowledge in the use of instruments for the Boiler Plant. Must have tact, energy and a Public School education (not necessarily University). State full particulars.—Address, F 295, Offices of ENGINEERING.

Contractors' Engineer Agent

WANTED for Headquarters by Firm of Reinforced Concrete Specialists. Knowledge of Reinforced Concrete Design preferable; must be neat and capable draughtsman and up-to-date experience in pricing and practical knowledge of carrying out work. State salary required, age and previous experience.—Address, F 300, Offices of ENGINEERING.

BURGH OF GIRVAN.

RESIDENT ENGINEER FOR HARBOUR WORKS.

The Girvan Town Council invite

Applications for the Post of

RESIDENT ENGINEER in connection with proposed Harbour Improvements. Applicants must have experience of Harbour Works and be accustomed to diving, and capable of keeping careful cost records and accounts.

Applications which should be accompanied by copies of testimonials, stating salary required, should be submitted to JAMES SMITH, Town Clerk, Girvan, not later than 18th July. F 278

Assistants (Three) Re-

QUIRED by the GOVERNMENT of HONG KONG for service in the Architectural Office of the PUBLIC WORKS DEPARTMENT, for a period of three years with possible permanency. Salary £460, rising by annual increments of £20 to £500 a year, and thence (if appointment is made permanent) to £950 a year, payable locally in dollars at the Government rate of exchange, which is at present fixed at 2s. to the dollar. In addition a strictly temporary exchange allowance of 20 per cent of salary is at present paid. Candidates, unmarried, 24 to 32 years of age, must be duly qualified Architects' Assistants and Associates of the R.I.B.A., should be experienced in design and the preparation of working drawings, details and specifications, and have some knowledge of quantities. Experience in the design and erection of steel framed buildings and a working knowledge of reinforced concrete is desirable.—Apply at once by letter, stating age, qualifications and experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, Westminster, S.W. 1, quoting M/129/9. F 317

COUNTY OF SURREY.

HIGHWAYS AND BRIDGES DEPARTMENT.

ARTERIAL ROADS.

Applications are Invited for

the APPOINTMENT of an ASSISTANT RESIDENT ENGINEER to act under the directions of and to assist the Resident Engineer in the supervision and construction of the Kingston By-Pass Road. Salary at the rate of £8 per week.

Applications in writing stating full particulars of appointments held and experience on similar works, accompanied by references, should reach the undersigned not later than Friday, the 18th of July, 1924.

Forms of application, and further particulars, may be obtained from the undersigned. Stamped addressed envelope should be forwarded.

W. P. ROBINSON, A.M.Inst.C.E.,
County Surveyor.

County Hall,
Kingston-on-Thames.
7th July, 1924. F 284

COUNTY BOROUGH OF WOLVERHAMPTON.

DEPUTY WATER ENGINEER.

The Council are prepared to receive

Applications from Qualified

Engineers for the above position, for which a salary and bonus of £400 per annum will be paid, advancing by two annual increments of £25, subject to satisfactory service.

The Council having adopted the Local Government and other Officers' Superannuation Act, 1922, the appointment will be subject to percentage deductions in accordance with the provisions of the Act.

Applications, stating age, experience, qualifications and present salary, together with copies of three recent testimonials, must be delivered to my Office before Noon on Friday, the 18th inst.

Canvassing members of the Council personally or otherwise will disqualify Applicants.

(Sgd.) H. A. B. WOODWARD,
Water Engineer and Manager.

Town Hall,
Wolverhampton.
2nd July, 1924. F 309

PROCEEDINGS OF THE FIRST WORLD POWER CONFERENCE.

IN our issue of last week we dealt with the first two days' proceedings of the First World Power Conference, and may now pass to a consideration of the papers and discussions of subsequent days. The Conference is planned on such extensive lines, and covers such a mass of papers and meetings, that it is not possible to deal in detail with every item making up the proceedings. The third day, *i.e.*, Wednesday, the 2nd inst., was entirely given up to Section M, the proceedings of which were likely to interest a large proportion of the members of the Conference, being concerned with the economic aspects of power resources. The papers covered by this section were not, however, in general of such a technical character as to render them suitable for detailed consideration in our columns, and we accordingly give a general account of the meetings, summarising the papers in conjunction with the discussion which they aroused. On subsequent days the various sections of the Conference met independently, usually three sections at a time, and a more specifically technical type of paper was brought under review. We deal with these sectional meetings of Thursday, the 3rd inst., and Friday, the 4th inst., below. It has not been possible, however, to deal in any considerable detail with all contributions even to the sections which were concerned with technical matter falling closely within our province, and while certain of the papers will be found abstracted elsewhere in this issue, others will be found to have been summarised in connection with our report of the discussions.

Before proceeding to an account of the sectional meetings, mention may be made of a further important social function of the Conference which formed an addition to those we dealt with last week. This took the form of a banquet and ball given by the American Committee to the delegates to the Conference. The function took place at the Hotel Cecil on the 3rd inst., and some 500 delegates assembled. The chair at the banquet was occupied by Mr. O. C. Merrill, Chairman of the American Committee, who, in his introductory remarks, made reference to the excellent work of Mr. D. N. Dunlop in organising the Conference. An address of welcome was delivered by Dr. Arthur T. Hadley, former President of Yale, who said the guests of the various nations would never be able to repay the English nation for the hospitality extended to visitors to the Conference. That hospitality has lasted from the beginning of electrical science, and nothing had so much touched the heart of Benjamin Franklin as the welcome extended to him in London, as a man of science, even in times of grave political differences.

Replies were made by Mr. P. J. Pybus, on behalf of the English Committee, Dr. M. Kamo for Japan, M. E. Uytborck for Belgium, and Mr. John Murphy for Canada.

SECTION M—ECONOMICS OF POWER PRODUCTION AND DISTRIBUTION.

This section of the Conference was opened on Wednesday morning the 2nd inst. by Sir Robert Horne, who stated that the economic and financial aspect of power production and distribution was, to him, the most important question to be discussed and settled as far as this was possible. At the present time the world was crippled by reason of the war, and Europe was in a state of confusion. The war had destroyed vast sums of money and had wiped out the economies of past years. At the present time there was not sufficient money in the world to allow of maintaining the pre-war standard of living. After dealing briefly with the work done after the Napoleonic Wars in developing the coal-mines and the various applications of steam power, Sir Robert stated that the only field where he could see a chance of progress for the present and immediate future was the field of electricity; there was no other means he could think of apart from the general development of electric power for improving the general situation. Vast resources could be turned to account. Our coal was being misused to a very great extent and could be made to develop three times as much power as it did now, by a better application to electric generation. Other Continental countries had, no doubt, been compelled to develop electricity supply more actively than we, yet they had shown us an example that we should do well to take into account. He looked for beneficial results from the conference, in which 40 countries were taking part, for all the delegates had met together with one view only, namely, to set progressive forces in action for the benefit of the whole of mankind. Governments and municipalities could help, and private enterprise was ready to give its enthusiastic support.

Mr. D. B. Rushmore stated that all the delegates were searching for the truth in regard to the different problems involved. The world was in a state of evolution economically, socially and politically. The rate of change should, however, not be too rapid, and one was not to undervalue what had already been accomplished whilst considering new means. The problems under consideration, and the methods to be employed were different in the various countries. The question of power development in the United States had hitherto been somewhat retarded by uneducated public opinion, but now a modern form of development was being worked to; there was a better centralisation of all resources, followed by better results. The employees were made participators in the concerns, and the basis had been laid for a common association. The effort being made was an intelligent co-operative one, allowing the maximum individual initiative and enterprise.

Mr. C. Kleman read his paper on "The Power Policy of Sweden." He stated that in Sweden the waterfalls were owned by the State, towns, municipalities, private companies, various associations and private persons. The State obtained the necessary capital by loans, as also did the towns and municipalities; in both these instances the revenue had to cover all expenses, yield a sinking fund and interest. The large private power companies usually obtained loans on the security of mortgages on the power station and the transmission lines. Where large sums were needed, bonds were issued through a bank, and such bonds had in some cases been sold to foreign countries. The revenue from the sale of power to consumers was used for paying the interest on the loan and to amortise it in a stated number of years. The State also helped by loans the formation of comparatively small hydro-electrical power stations.

Sir Philip A. M. Nash then read his contribution on "The Economics of World Power." He stated that the economical aspect of world power had hitherto been neglected as compared with the consideration given to the purely technical aspect; there was in consequence a great disproportion in the present development of the two standpoints. Much work was still required to be done to place these two sides of the question on the same level. He reviewed the situation as it applied to various countries. In regard to this country, our coal could be used much more economically than it now was. Fuel supply was not the problem requiring solution; the problem was fuel economy. Almost anything could be used as fuel for steam raising, but it was the utilisation of the steam that was uneconomical. The energy in coal should be applied to direct use, and the cutting down of the waste which now obtained was the task to be dealt with. The economical aspect of the problem had a very wide social importance. Compared with the United States, the degree of electrification in Britain was very small. Comparing the figures for the years 1912, 1917 and 1922 of the progress made in five American States with that made in five British undertakings, the figures pointed to one fact, among others, that economically the utilisation of electric power on a large scale had found complete justification. No one, he added, could fail to see that electricity must play a tremendous part in the recon struction of the world; all conditions showed that this country was on the point of carrying out great developments in this sphere and it was a good thing that the first world-power conference should take place in London. What the world needed was co-operation, and that was the spirit in which the conference was being conducted. He was pleased to take part in it.

Dr. H. J. van der Bijl, delegate of the Union of South Africa, said the Union found the best means to be production and distribution by large stations; electric energy could not be regarded like any other commodity, and no competition or duplication could take place; electric power was a means of great importance for the purposes of industry. There was in the Union of South Africa an Electricity Control Board, on similar lines to the Electricity Commission in this country. Government ownership and private enterprise were combined. State undertakings were not very efficient, but the State credit made it possible to raise loans at a low rate; the Board operated freely, whilst enjoying a certain amount of State backing. It appointed its own staff; it operated the power stations, and at the same time produced and sold the by-products, doing, in fact, all that was necessary to lower as much as possible the price of current. It could obtain financial aid from Government during the first four years; it was not required to pay a dividend. In the Union, there was no water power to speak of; where it could be turned to account the cost was high and it was preferred to look to coal as the source. There was a large amount of coal available in the Union and the power stations would be concentrated on the coalfields. The price of coal made current production in the Union as low in price as in any other part of the world. The stations were easy to build, and that fact combined with the low price of coal made it possible to produce current in the Union at a cost comparable with that of most water power schemes. The question resolved itself into burning the coal economically, coupled with the utilisation of the by-products.

Here Sir Ernest Harvey was invited by the chairman to read his paper on the "Effect of Depreciation Currencies and International Financial Conditions on Power Development within the British Empire." In this the author referred to the consequences of the abuse of note issuing and the neglect of regular tax collection in various countries, adding that the effect of this policy on enterprise had been to clog the accustomed channels into which capital for power development used to be directed. Fluctuations in exchanges had kept British capitalists away from foreign enterprises; hence larger capital sums had been available for power distribution schemes throughout the Empire. The conclusions intended to be suggested by the paper were that British currency must be restored to pre-war value and that the gold standard must be re-established. There must be no spoliation on the part either of power companies or of the governing authorities of the districts where companies operated. The United States Treasury must alter its constitution and prevent cities and states from issuing tax-exempt bonds. Europe must become able again to participate with London banking houses in

commercial finance. Taxation and the cost of output of labour (not necessarily wages) must be reduced in the interests of the capitalist and the worker. So far as England alone could contribute to any of these developments, it was certain that she would soon do her share.

Mr. W. S. Murray, a delegate of the United States, said that electricity was the word which had gathered the Conference together. It was now possible to build large machinery to generate current and to deliver this over large distances without commercial loss. The true economies in the future had to be related to a correct allocation of power and load. He characterised "diversity economy" as the ability to produce the greatest amount of electrical capacity at a minimum cost.

Dr. J. F. Crowley thought that the question of economics resolved itself not so much into the lowering of the cost of power as in rendering power more generally available. He thought that the recovery of by-products in a power station did not pay; it was not economical for a power engineer to recover them. The improvement of the load factor was the direction in which to work; the off-peak powers had to be utilised to the full. Alternate sources of power were of great interest in some countries, in Canada, for example, but such was not the case in this country, except for a few instances in Scotland. The problem in England was to conserve our coal. He advocated the passing of resolutions by the Congress so as to facilitate legislation on a number of points by the respective Governments.

Mr. H. M. Addinsell, an American financier, after explaining how the United States banks, insurance companies and savings banks were interested in public utility services, added that one of the desiderata to be aimed at was, to use an American saying, more business in Government and less Government in business.

Mr. A. Pescatore, the Chargé d'Affaires of Luxemburg, said that his country, in comparison with its size and population, was one of the largest coal consumers of the world. Hydraulic power was practically non-available. The larger part of the coal used came from the Ruhr before the war. Since the war, the country had generally received only about half the fuel it needed for its industries. There should be as much freedom as possible in the coal trade, and he suggested that the next Conference should establish relations with the League of Nations, or another body, to consider this point.

At the meeting on Wednesday afternoon, Mr. Arbelot, Vice-President of the French National Committee, occupied the chair.

The only paper read was that contributed by Mr. F. R. Low, Editor of *Power*, New York, on "The Social Aspect of Power Development." It stated that in 1869 there was available to each wage-earner in the United States 0·6 of a horse-power; by the last census, that of 1919, this had grown to 3·25 h.p. In 50 years the power available per workman had increased over fivefold. It had placed within the means of the day labourer comforts, conveniences, enjoyments and luxuries that would, without it, if producible at all, have been available only to the most opulent. The spirit which animated the mob which destroyed Hargreaves newly-invented spinning jenny had opposed itself to the introduction of many labour-saving machines and methods since. Dealing particularly with water-power plants, the author said that those in the United States were leased upon terms which afforded a fair opportunity of profit to initiative and enterprise, a fair rate for the power when used by the public, security for the capital invested, the property returning to the Government at the end of 50 years, at the Government's option, upon repayment of the net amount invested therein. Uneconomic competition between the producers and distributors of power was avoided by treating them as controlled monopolies; the light and power companies had stabilised their industry and won the confidence of the investing public and of their own consumers by co-operating in such control.

Mr. J. P. Noonan, President of the International Brotherhood of Labour, United States, said that labour had no quarrel with improvements and labour-saving appliances, because they increased the productivity of the workman and the sale of his products. The men representing the great financial interests and the technicians, both working out their schemes, formed one element, but another element was still a necessary component part, namely, actual labour. Yet another element was formed of the public, or the body of users and potential users of the product. Labour could and did stand ready to co-operate with all the other elements involved, for removing the fetters by which the power industry might find itself shackled here and there. It wanted the financiers and technicians of the world to allow it to co-operate.

Mr. C. D. Busila, the delegate of Roumania, gave a recapitulation of the coal, liquid and gaseous fuel, and water-power resources available in his country, and enumerated the various new laws passed for regulating their utilisation.

Mr. Guido Semenza pointed out that Italy commenced utilising her water power in 1893 and 1895 and developed her resources very rapidly, and now distributed the current produced over great distances. Her water-power installations proved of immense value to her during the war. Notwithstanding these installations, coal could not be dispensed with, and her coal imports were still very large. The water-power installations were mostly due to private enterprise; only a relatively small part was State or municipally owned. The State gave a grant to private concerns for establishing a complete scheme, the grant lasting 50 or 60 years, at the end of which time the State became the owner, with the option of leasing the installation.

Mr. Montanes called attention to the fact that his country, Spain, was admirably situated for the development of power, since she had large coal-fields in Asturias, Murcia, Burgos, Pennaroya, all waiting for development, also large water-power resources, these latter mainly in the Pyrenees district. Many enterprises were in the hands of foreign companies, and financed by British capital. If all her resources were fully developed, they would enormously increase the wealth of the whole world. Their development by Spain alone was rendered difficult by the lack of large Spanish banks, the existing banking establishments not dealing usually with the negotiation of loans. He advocated resolutions being passed suggesting that action be taken now for the development of all the available Spanish resources he had referred to.

In briefly recapitulating the proceedings of the day the chairman, Mr. Arbelot, laid stress upon the great increase in power stations in the United States and in England. The increase was also marked in France. The question was as to whether the increase would be continued in the future. Another question was as to whether the modification of the peaks had been carried in all countries as far as it could be. One of the authors had referred to what he (the speaker) would term the present "crisis of confidence" and had given remedies; a question under this head was to find out whether unanimity reigned, for instance, in the re-establishing of the gold standard. Some members no doubt were of opinion that the return to the gold standard was not a necessary condition for furthering power development throughout the world. State interference had been criticised; was there also unanimity on this point? Such were some of the questions which had been raised during the day and which had to be solved.

A paper by Mr. B. Stuevold-Hansen, Director-General of the Watercourse and Electricity Service of Norway, dealt with "The Financing of Loans for Power Development." It stated that the supply of electricity in Norway was at first taken up by private enterprise, and the first plant for power distribution, put down in Skien in 1885, was a private one. Very shortly afterwards, in about 1890, the first municipal electricity stations were established in Christiania and Hammerfest. These formed the commencement of a development which, in a steadily increasing degree, has brought about duality in the work of producing power in Norway. Broadly speaking, by far the greatest activity in connection with the general supply of electricity in that country was at present of a communal kind, whilst the supply of current for the large electro-thermic and electro-chemical industries was in the hands of private undertakings; quite 90 to 95 per cent. of the capital of these industries was privately subscribed. In the undertakings for general supply purposes, on the other hand, it could be safely estimated that the private capital invested amounted to only about 10 per cent., whereas the community and the State had participated to the extent of about 83 and 7 per cent. respectively. The localities where a general supply through private enterprise existed to any marked extent were in the more densely populated, Eastern part of the country.

The independent position of Norwegian communities as economic units had exerted its influence on the development; they had become accustomed to arrange their own affairs to steadily increasing degree; both in their right of imposing taxes and in their opportunities for borrowing money they had been but little restrained by interference, or supervision on the part of the State. Except for the comparatively small installations for private use, up to January, 1923, power plants, transmission lines and distribution systems for the general supply had involved an expenditure of about 43,000,000*l.* Of this amount, the share of the Communities (towns, rural communities, and other administrative areas) was about 36,000,000*l.* The State figure was about 3,000,000*l.* and that of private enterprise about 4,000,000*l.* The capital invested in the plants for the general power supply had chiefly been raised by loans. At the end of June, 1923, the total debt of the community on account of electrification amounted to about 33,000,000*l.*, or about 9 per cent. less than their total capital outlay. The capital invested in power plants for the electro-chemical and electro-thermic industry—*i.e.*, for purposes other than those of general supply—was not known with much accuracy. This could, however, be put down as from 41,000,000*l.* to 44,000,000*l.*, including the factories. Some plants for electric tramways and railways stood in a class by themselves; the largest of these was a plant built by the State for the electrification of Government railways.

In order to create a firmer basis for the development of the general supply of power, "The Royal Committee for Electricity Supply" was appointed by Government in 1919. This committee was formed to investigate the possibility of electrifying the whole country by a National Supply Scheme, and to draft regulations for the better organisation of the supply, &c., for co-ordinating the existing plants. It published its proposals in 1922–1923. The proposals aimed at supplying the inhabitants with power in five stages, ranging from 50, to 100, 150, 200 and 250 watts per head per annum, the cost of each stage varying from 13,000,000*l.*, for 50 watts, to 18,500,000*l.*, for 250 watts. The scheme was still in abeyance, for financial reasons. Proposals in regard to loans which had been under consideration for some time past and were still being contemplated comprised the formation of a Water Power Mortgage Bank, or the formation of a Community (urban and rural) Bank, or of a Community Electricity Bank. In each of the three instances the State would bear the final responsibility, but every one of the three schemes pre-supposed that by expert management and supervision there would be so satisfactory a security for the money lent that practically no loss would be incurred to be covered by the State. At the present time the Government was giving its attention to the three proposals and might bring in a Bill which embodied points from each; it was hoped that a decision would soon be taken, although the present time was not a favourable one for new enterprises of the kind.

A paper on "Power Development in Relation to Human Progress" was contributed by Mr. Julius H. Barnes, President of the Chamber of Commerce of the United States. After dealing with the rise in iron and steel consumption, the development of steam power, of the textile and other industries, the increase in consumption of coal and other fuel, and stating the social benefits in each case, Mr. Barnes said that the present age had brought new problems which required careful attention. The very strong economic forces now at man's command were very complex and had to be guided intelligently, otherwise there would be disaster. The evolution of industry on a power basis demanded enlarged capital and credit, and both these were vitally affected by Government policies. It should always be remembered that modern industry, served by machines and the power that ran them, justified itself by its social benefit.

Whatever retarded unduly the service of that great "machine of wealth conversion" would be a social injury to all the world.

SECTION M—GOVERNMENT POLICY AND POWER RESOURCES.

On the morning of Thursday the 3rd inst. the papers relating to Legal and Government Policy under Section M (Economic Aspects of Power Resources), were presented and discussed. Mr. Renzo Norsa, of Italy, presided, and after briefly surveying the whole field of the subjects for discussion called upon Mr. John Murphy, Vice-Chairman of the Canadian Committee, to present the paper prepared by Mr. Lawrence J. Burpee on the International Joint Commission and the International Water Powers of Canada. In this paper the resources owned jointly by the Dominion and the United States, which represented approximately 8,000,000 h.p., were described. The scheme came into operation after the signing of a treaty at Washington in 1909, designed to prevent disputes regarding the use of boundary waters. The control was vested in three representatives of Canada and three of the United States, and the whole scheme had proved successful and useful in preserving amicable relations between the two countries.

Sir Philip Lloyd-Greame said it would be generally accepted that it was to the interest of governments generally to encourage and foster the fullest developments of power undertakings within their territories. The governments had therefore to create conditions facilitating the enterprise and in abnormal times use their credit for that purpose, and even contribute financially to the undertakings. The British Government used three methods of dealing with such ventures. Under the Trades Facilities Act the Treasury guaranteed the principal and interest of capital issues for the purpose of carrying out suitable undertakings if the plant was manufactured in the United Kingdom. By the Overseas Credit and Insurance Act the Government guaranteed bills drawn against the shipment of British manufactures, where comparatively long credit was required. Under another scheme of Direct Grants-in-Aid, controlled by a special Unemployment Grants Committee, grants were made to the extent of 50 per cent. of the interest on loans raised for a period of not less than ten years, to ensure the early undertaking of schemes not likely to produce revenue for a considerable period.

M. Diény then presented a paper on French Legislation, by M. Domergue and M. Lecat, in which it was stated that the erection of power stations in France was not controlled by any particular legislation or regulations other than these relating to all steam and hydro-electric schemes. Those relating to steam-operated stations were only drafted to ensure a reduction of the risks and inconveniences they may cause. The regulations dealing with hydro-electric stations were more far-reaching, since the State did not merely exercise a general control but also assumed full managerial rights.

Captain H. von Heidenstan, a Swedish delegate, said that the Government legislation of Sweden was generally of the same type as that in force in Britain. The development by private ownership was its basic principle, but regulations were in force to ensure the maintenance of public interests.

Mr. J. G. Bellaar Spruyt presented the paper contributed jointly by Dr. E. A. Shoon and himself in which it was shown that the supply of electricity in the Netherlands was regulated only to a very small extent by Act of Parliament. This branch of industry had, however, been handicapped by coming into conflict with the vested interests of third parties. A large number of municipalities had electric power supply schemes, including many small ones which generally obtained their current from inter-local undertakings. The plan of establishing a State concern which would eventually obtain control of and co-ordinate the working of all generating stations was abandoned. It was anticipated that a new Royal Commission would extend to private enterprise much greater freedom and make them more secure from the interference of Provincial Governments.

General Guy E. Tripp, of the Westinghouse Electric and Manufacturing Company, New York, contributed a paper on the Relation of Power Development to Industrial and Economic Progress. In his paper the author emphasised the importance of obtaining cheaper power which could be obtained by the introduction of super-power stations. Should there be no undue restriction in a few years there would be nation-wide power systems with high-tension trunk lines supplied not only from water powers and supplementary steam stations, but also from other cheap sources, such as the by-products of industrial operations like gases from blast furnaces and coke ovens and the residue after the extraction of gases from coal. The manufacturing establishments of the United States had installed about 17,000,000 h.p. of steam plant, and if it was replaced by electric power from a general system a saving of 75,000,000 tons of coal a year was anticipated by some authorities. It was estimated that there was sufficient density of traffic on perhaps 70,000 miles of railway, about 30 per cent. of the total, to warrant electrification. There were large opportunities of thereby saving much of the 175,000,000 tons of coal used each year on the American railways. Development was being pursued vigorously by private concerns and Government ownership was not essential to the accomplishment of super-power schemes. Low cost of power depended upon factors which were shown by long experience to be best managed by private interests and covered a field in which Government activities had always been inefficient. Under systems of public regulation, the interests of the public were better protected than under public ownership.

Dr. Arthur T. Hadley, ex-President of Yale University, U.S.A., then submitted his paper on Private *versus* Public Ownership and Operation, in which he endeavoured to show that State working of power resources was little short of suicidal. This paper we hope to reprint in a later issue.

Mr. John W. Lieb, in the absence of the author, Mr. Carl D. Jackson, referred to the paper on Public Utility Regulation in the United States. The scope of regulation was, he stated, controlled by the constitutional limitations of the Federal and State Governments. The Common Law of England was the basis of all legislation relating to public utilities in America. There were, however, many anomalies, such as the prohibition by some States of the export of water power and coal. It had become a recognised part of legislation to consider public utilities as national monopolies. In the public interest their activities had to be regulated, but they had also to be protected against unfair competition. The principal objects sought by regulations were the securing of adequate and safe service, the prohibition of discrimination in rates and service, and the establishment of reasonable rates for the services rendered.

Dr. Wouter Cool submitted the paper of Professor J. N. Van der Ley, of the Dutch East Indies, on Legislation for Electricity Supply in New Countries. The first consideration in drawing up regulations for new countries was that no electric power plant should be erected without a concession from the Government. Power companies for the distribution of electricity should be started on a community basis, in which the various local boards should take part. The tariff policy should be founded primarily on the popularisation of the use of electricity.

Mr. Harold V. Bozell introduced the paper on "Government Policies in Relation to Power Development and Distribution," prepared by Dr. Herbert Hoover, the Secretary of Commerce of the United States, in which the progress of the exploitation of electric power in the United States was dealt with on broad lines. Attention was called particularly to the influences which had made advisable the centralisation of supply and interconnection of systems. The control of the American Government was reduced to an absolute minimum and acted simply to prevent abuses. It was the business of Government to preserve an open way for the exercise of individual initiative and not to substitute its own activities for that initiative. Governments should regulate and control but should not manage or operate. In the stress of international competition that nation which left its people most free from hampering restrictions would progress fastest.

Colonel Batty, of India, spoke about some of the difficulties of Government operation of utility services. In railways there was little but failure, and in irrigation schemes it was apparent that they could not reduce the cost of water without a political upheaval. In water power schemes they had three parties to deal with, capital, labour and the consumer. The board should be representative of these three interests. The consumer became a good salesman when a rebate was given to him proportional to the profits. If they had to have the scheme run by a Government department the solution was only to be found by handing over the management to men who could be trusted and they must be remunerated proportionately to the profits. Freedom from political interference was difficult to secure, for when profits went to the Government interference began.

Mr. Sibley, of California, said that the saving to the people effected by the cheapening of the production of electricity, due to the improvement of plant, was enormous and no legislative activity should prevent or restrict the introduction of modern methods. One good way of raising money for electricity undertakings was to make an appeal to the consumers' self-interest. Were the cycle of wealth production which followed the cheapening of power production properly demonstrated, stock could be sold to the people.

Dr. George Otis Smith, of U.S.A., summed up the situation as regards Government operation by saying that he was in favour of Government regulation always but never of Government operation.

Mr. Renzo Norsa, the chairman, then closed the discussion.

SECTION C—PREPARATION OF FUELS.

The proceedings of Section C (Preparation of Fuels. Fuels Generally and Coal) were opened on Thursday, July 3, morning, by Dr. D. S. Jacobus, of New York, for many years professor of engineering at the Stevens Institute of New York, now connected with the Babcock and Wilcox Company. In taking the chair, Dr. Jacobus appealed to members to give in order to help and to receive. In view of the large number of papers on the agenda (14), he suggested that members, in presenting their papers, should confine themselves to essential points and that, apart from immediately-arising questions, the papers should be discussed in groups. We follow the sequence adopted.

Professor Hugo Strache, chief of the Fuel Testing Department of the Vienna Technical High School, advocated in the first paper taken the "Complete Gasification of Coal," particularly by the "double-gas" process. Up till recent decades gas had been supplied for two distinct purposes, for light and for producing power and high temperatures; water gas had afterwards bridged the gap between coal gas and producer gas. But water gas required a good coal and could only be produced together with coke. The new "Doppelgas" might be regarded as a mixture of coal gas and water gas, as it was directly generated from coal and had a higher calorific power than water gas 100 kg. of a coal of 7,000 calories would yield 150 cub. m. of water gas of 2,800 calories per cub. m., a total of 420,000 calories, and 156 cub. m. of double gas of 3,200 calories, a total of 500,000 calories of double gas.

In the double-gas producer the coal was fed into a retort from which it would sink into the large gasifying chamber underneath which was provided a revolving grate through which air was blown for the gasification. The gases of combustion passed around the retort (outside it) into the lower portion of a steam superheater, where they were completely burnt, heating the checker bricks and escaping still hot enough for steam raising. The valves were then reversed; steam was sent into the superheater and from there into the gasification chamber, in which now water gas was formed; this gas passed at high temperature into the retort above, acting directly upon the lumps of coal in their downward movement and coking them at lower temperature than in an externally-heated coke oven; thus 8 kg. of a low temperature tar (Urteer) were produced (against 4 kg. of tar in a coke oven), and a high yield of ammonia was also obtained. When the gas fire was cooled down too much by the steam, the process was once more reversed.

Dr. Strache gave heat balances of the double-gas

producers installed at Graz in 1920 and at Chemnitz, 1923. Any coal could be used; large gas holders were not required and, owing to the high calorific power, the distribution cost, always a high item, was lower than with other gas, especially for distances above 40 km. He did not recommend the system for small towns; for large plants, combined with steam-power electricity works, it had great advantages, because the hot-gas supply could be increased at will in the double-gas producer by prolonging the hot blast. There were already a large number of double-gas plants in operation, in the former Austro-Hungary monarchy and also in Germany and Italy and at Helsingförs. The present German standard for town gas was 4,000 calories; but that figure would probably be reduced.

In a second paper, on "The Fuel-Testing Department of Vienna," Dr. Strache outlined the work of this branch of the Technical High School, where students devoted the last two years of their four years' course of study especially to heat.

The paper by Mr. Gordon Adam, of the Gas Light and Coke Company, on "Liquid By-Products of Coal-Carbonisation as a Source of Power" was presented by Mr. F. M. Potter. It pointed out that in this country vertical retorts were gradually replacing horizontal retorts; the 16½ million tons of coal carbonised here yielded 18 million gallons of tar. Per ton of coal, horizontal and vertical retorts and coke ovens yielded respectively 10·5, 14, 8½ gallons of tar. The benzene hydrocarbons in the gas was recovered by means of washing, by activated charcoal (in Germany and America) and by silica gel (America). The charcoal was obtained by a preliminary carbonisation of peat, wood, or lignite; the product was impregnated with iron or zinc chloride, washed, and finally carbonised. The use of silica gel was recently noticed in our columns. Mr. Potter had found the benzole recovered by charcoal and silica freer from gums than benzole recovered by washing. The paper further discussed the hydrogenation of coal-tar products, the so far uncertain possibilities of naphthalene (tetraline, decaline) and phenol derivatives, and the Bergius treatment of low-temperature tars with hydrogen at 400 deg. C. and 100 atmospheres and more, which was said to have given encouraging results with lignite tars; he also referred to the work of F. Fischer at Mülheim (not Mannheim, as the paper prints).

Professor H. E. Armstrong emphasised various points regarding low-temperature carbonisation. The days of raw coal, apart from anthracite, were numbered; success in the production of a smokeless solid fuel by low-temperature carbonisation could only be obtained when the chemist and engineer were led to, if not forced to, work in co-operation. The removal of mineral matter should take place immediately after raising the coal; that, and the protection of the coal against oxidation during the grinding, was largely a chemical problem. Low-temperature coal oil ("coalit oil") differed entirely from ordinary tar oil and should be treated differently; its chief use would probably be as fuel oil. Professor Armstrong showed some coalite made from the very friable Kent coal. The low temperature process had its limitations, since the exchange of heat through the walls even of iron retorts and within the mass was slow. But Mr. E. V. Evans (South Metropolitan Gas Co.) had discovered that caking coal, ground and mixed with some ground coke or non-caking coal and briquetted by pressure, could be carbonised at the usual high temperatures of town gasworks, yielding a gas similar in quantity and quality and an easily combustible coke. With respect to the general problem of the smokeless-fuel industry, Dr. Armstrong considered that neither here nor in America had any process been carried to complete practical and economic efficiency; no one had yet made a gas-tight plant. The Fuel Research Board had spent 400,000*l.* without advancing the solution of the problem; it had failed for lack of leadership.

Surveying in the next paper the power resources of Sweden, Mr. Axel F. Enström, Director of the Ingeniörs - Vetenskaps - Akademien, stated that Sweden generated 3,000,000,000 kw.-hours of hydro-electric energy per year, and had before the war wanted for power and heat the equivalent of 11,000,000 tons of coal, half of which had then been imported, but the imports had gone down to 2,500,000 tons. The coal mines of the country only yielded 400,000 tons yearly. Forests covering 54 per cent. of the country supplied the equivalent of 5,000,000 tons of coal. Charcoal, equivalent to 700,000 tons of coal, was produced in the old-fashioned piles and in kilns of the shaft and other types.

In the Aminoff channel kiln the wagons containing the wood were continuously circulating through a long tunnel inclined both ways; the by-product recovery was not so complete as in the shaft kilns. The shale-distillation was also important. These oil shales were piled up alternately with limestone in open-air lime kilns; the Bergh-Larsson shale retorts will be described in another paper. The annual peat production had increased during the war from 75,000 tons to 400,000 tons, but had again decreased since; the production of refined peat-fuel was not yet an economic success. Power alcohol had been made during the war by works having a capacity per year of 20,000,000 litres of 95 per cent. alcohol, erected by the Aktiebolaget Ethyl and others; this industry had declined after the war, but was reviving.

With regard to the use of charcoal in gas producers for heavy motor-cars, to which Mr. Enström had referred, Professor A. Brunschweig, of Paris, mentioned that the difficulty was the purification of the gas. Mr. Taussig, of Vienna, added that they had paid as much attention to these producers in Austria as in France.

Mr. C. F. Hirschfeld, chief of the research department of the Detroit Edison Company, surveyed in his paper the fuel resources of the United States at considerable length, dealing with coal, its preparation and storage at consuming plant, low-temperature carbonisation and fuel oil, gas (natural and blast furnace) and combustion control.

Dr. Franz Fischer, director of the Kaiser Wilhelm Institut für Kohlenforschung at Mülheim on the Ruhr, stated in this paper that to obtain from coal suitable fuel oils (not rich in anthracene and naphthalene which solidified) the distillation should be conducted at temperatures below the 300 or 450 deg. C. at which bituminous substances began to decompose in different coals, and the vapours should quickly be removed from the still or retort and condensed to avoid dehydrogenation and disintegration into gases. The process could be carried out in retorts or in producers. The semi-coke in the retort would be very friable unless the coal was compressed in the furnace while plastic, by means of a plunger (Olin and Parr), or a roller (in a horizontal retort, Fischer); but that was difficult technically. From 10 per cent. to 15 per cent. of the tar obtained would boil below 200 deg. C., the bulk boiling between 200 deg. and 250 deg.

These statements referred to low-temperature distillation. Hydrogeneration of coal, *i.e.*, removal of all its oxygen (about 0·87 per cent.) and introduction of more hydrogen, could be effected, at high pressure and temperature, by means of hydriodic acid (Berthelot) or by means of sodium formate; by the latter method Fischer and Schrader had made 45 per cent. of lignite soluble, but the process was still very expensive. They therefore treated the lignite with water and carbon monoxide (which would momentarily give formic acid) at 400 deg. and 140 atmospheres. The yields were better than with the Bergius hydrogeneration (by means of molecular hydrogen), but the process had not yet given a motor fuel. Professor Fischer and Tropsch then tried a synthetic process, starting with a water gas (rich in hydrogen). Compressed to 100 atmospheres or 150 atmospheres at 410 deg. C., and passed over iron filings impregnated with alkali, water gas from any coke or semi-coke yielded an oil, a light yellow, thin liquid, smelling like acetone and amyl alcohol, of density 0·8289 and melting point 30 deg. C. This crude "synthol," which consisted of carbon, hydrogen and oxygen in the ratio 69·3 : 12·2 : 18·46, 88 per cent. of which boiled below 200 deg., proved an excellent motor fuel, mixable in all proportions with alcohol, benzene and gasoline. The yield of oil represented only 8 per cent. to 10 per cent. of the water gas; but by passing the vapours at ordinary pressure once more over the catalyst, a yield of 30 per cent. was realised. The synthol contained alcoholic constituents which, by further high-pressure treatment, were converted into a gasoline, for which the name "synthin" was proposed. Much depended, of course, upon the experimental conditions, and, as Dr. R. Lessing pointed out in the discussion, a high rate of hydrogenation can hardly be expected considering how little hydrogen is bound in coal. To Mr. Haanel's question whether the Bergius process was really a success, Dr. Fischer had no further reply.

Dealing briefly with this problem and particularly with the work of the Fuel Research Board, Dr. C. H. Lander, M.I.Mech.E., director of Fuel Research, said that he agreed with Dr. Armstrong that complete success had not been attained. But he differed from the statement that no serious attempt had been made; the work was going on and plants were in operation. The great difficulty was the translation from the laboratory scale to the large works scale; there was no correlation as in other engineering problems, *e.g.*, in ship and bridge design. In touching upon a few points he remarked that extravagant credits were often taken for the ammonia produced; the ammonia recovery from the diluted liquor obtained was hardly worth while at present. The briquetting process of Messrs. C. R. Sutcliffe and E. C. Evans (not the process to which Dr. Armstrong had referred) had been investigated at the Fuel Research station; they had found that very fine grinding and high pressures were not required, but they had been troubled with dust. They were devoting particular attention to the oils from coal. Ordinary low-temperature carbonisation oils were not mixable with most natural petroleums and not suitable as fuel oils for marine purposes, because pitchy deposits were formed. That difficulty could be overcome; Dr. Lessing did it by circulating the warm oil, after mixing it with a little petroleum, through pipes packed with Lessing rings.

The next two papers, by Mr. Goodenough and by Sir Arthur Duckham, came on again in Section D on Monday; we reserve comments.

On the suggestion of the chairman these papers were discussed together with special reference to the questions whether the use of raw coal should be continued to the present extent or whether the distillation of coal would become more generally practical. Sir Richard Redmayne said that domestic and power purposes had still to be distinguished. A low temperature coke would have to bear transport. As regards dirt, it was no doubt absurd, as Professor Armstrong had stated, to transport and to carbonise the dirty coal; but when the coal trade was good, the dirt per centage went up; much depended upon the miners; coal should be sold, as in America, on the calorific basis. Mr. Leonard Harvey advocated power-production in bulk by distillation with by-product recovery in continuous retorts of the Ford and of the "Fusion Corporation" rotary type, and use of the residue in pulverised form, on which he had presented a paper to Section D; the difficulties of the storage of pulverised fuel had been overcome.

Mr. Orrock, of New York, speaking next, said that low-temperature carbonisation could not pay with load factors of only 30 or 35 per cent. All plants made gas and coke which could be stored, because they retained their values; the prices of ammonia and tar fluctuated too much for justifying storage. The residue pulverised, at unknown cost, would not bear storage. Gasoline from low-temperature carbonisation oil had no chance in the United States at present; but that might alter. The purification and preparation of the coal was very important, and it should begin underground.

Mr. B. F. Haanel, chief engineer to the Division of Fuels, Department of Mines, Ottawa, said that the Canadian oil fields were threatening depletion and Canada wanted coal oils. Domestic fuel was a principal requisite in Ontario, and for their railway lines of 3,000 miles they could not but import anthracite. Their own coal was very friable, but the Fuel Board had erected large coke ovens, and they wanted to produce fuel oils. They had peat and lignite, the latter very different from European lignite, however, so that they had had to work out their own processes. He doubted the possibility of storing the pulverised lignite and coal. Professor

Armstrong, on the other hand, remarked that pulverised fuel could be stored and science demanded pulverisation; we pulverised fuel to determine its calorific value. Mr. Rodolpho Jaramillo, of the Chilian State Railways, said that they had used pulverised fuel in cement factories and for smelting copper for fifteen years, and had stored it for weeks; both their bituminous coal and their lignite were high in ash, 7 and 14 per cent., and the lignite contained 15 per cent. of moisture.

In presenting another paper, Mr. Arthur H. Lymn, of the Power Gas Corporation, remarked that some of the figures in his paper as printed were incorrectly numbered, and that the tables given there should be understood to apply to large plants. The paper described various methods of applying producers in comparison with each other and with modern direct-fired steam plants, without reference to suction-gas plants and to blast-furnace gas, but with particular regard to economic features, cost of installation and operation and value of by-products. With respect to the Holzwarth gas turbine, of which one of 5,000 kw. had been built, Mr. Lymn said that the high temperatures seemed to frighten people; but the average temperature, 750 deg. Fahr., was no higher and the conditions were no more arduous than in steam-turbine practice. Mr. Lymn compared combinations of low-temperature gas producers with either reciprocating engines or with gas-fired boilers and steam turbo-generator, or with gas turbo-generators under different load conditions.

This was the last paper taken in the morning session. The afternoon meeting, over which Mr. Haanel was to have presided, was abandoned to suit the convenience of members, and the discussion was adjourned till Friday morning.

In opening the Friday morning session, Mr. Oskar Taussig, director-general of the Tundloff-Dittrich Armaturen und Maschinenfabrik, Vienna, announced that, before proceeding to the reading of the remaining papers, the meeting would discuss the questions reserved by Dr. Jacobus, at the end of the first meeting, viz., what is the cost of pulverising fuel, and can the pulverised fuel be stored? Mr. Taussig added that Austria had been obliged to pay particular attention to the fuel losses incurred in bringing the coal from the bottom of the mine to the power station; that would be a subject for a future conference.

Mr. A. E. Douglas, of the Fuller Engineering Company, said that the United States had been using pulverised coal for twenty odd years, and were now pulverising 25,000,000 tons annually, some for steam raising. The cost varied with conditions, but their averages obtained in recent plants of daily capacities of 100, 200, 500 and 1,000 tons were for soft or bituminous coal, 45, 40, 34, 31·5 cents, and for anthracite or high-ash coal, 63, 53, 45, 43 cents; those costs comprised everything apart from fixed charges, interest and depreciation. The higher cost of the harder material was due to increased repairs and power; the kw.-hrs. per ton required for handling from car to furnace were 15 to 17 and 19 to 27 in the two cases. At the Lakeside plant of the Milwaukee Electric Company, where Fuller dryers, mills and transport system were used, the total kw.-hours per ton of coal were running to 17, and the cost per ton handled to 32 cents. A chart exhibited by Mr. Douglas showing the difference between first cost of stoker and of pulverised coal (unloading and handling fuel and ashes) was based upon a 70 per cent. load factor; with lower load factors conditions became more favourable to pulverised coal. The storage offered no difficulties nor fire risk, provided the pulverised coal was properly dried by hot air and stored in suitable bins, with hopper and bin slopes not less than 70 deg. Trouble would arise in flat-hoppered bins, but cement works and boiler plants disregarded the coal left in the bins when shutting down for weeks. In Seattle they had supplied pulverised coal, in barrels, to hotels and schools, but the expense of delivery was heavy.

Mr. H. S. Rowe remarked that 45 cents would be about 3*s*. Where was the advantage, especially for small boiler plants? It was claimed that cheaper coal could be utilised, but the increased demand would lead to higher prices. Mr. Douglas replied that engineers sometimes erroneously considered the 45 cents as additional to the stoker plant. They pulverised lignites (after removing free moisture) and anthracites in 27 countries, and the total cost of preparation was only a little, if at all, higher than the handling of coal and repairs on stokers, forced draughts, fans, &c., in stoker plants. Mr. F. van Herson, director of the Netherlands State Collieries, said that for small plants the Alvo pulveriser used in Belgium and France had advantages; but they required too much power for driving. Mr. Haanel remarked that the problem was very important for the Canadian railways and steam plants, though it looked at present as if they would want storage at many points of their railways.

Professor Pierce F. Purcell, of Dublin, and Peat Investigation Officer of the Fuel Research Board, submitted a very instructive, long report on the distribution of peat in Europe and other parts of the world, and on its physical properties, dehydration, winning and utilisation, from the industrial point of view, giving a great deal of technical detail. About two-thirds of the 90 per cent. of moisture were retained by the colloidal material and could not be expressed. When about half the moisture had been lost, air drying should be carried out in large clamps to prevent cracking of the peat. Air drying could yield a peat of 6,000 to 7,500 B.Th.U. per lb. The economic development of peat had, during the last 15 years, profited much from the macerating machines and other appliances of Wielandt, Strange and Baumann-Schenck in Germany and of E. V. Moore in Canada. Mixing of the raw peat with dried peat or coke did not really dry the peat, but it facilitated the dehydration in the Madruck and other presses. Haanel and Moore in Canada had simplified the distribution problem on new lines by using, on the Alfred bog near Ottawa, a modified Anrep (Swedish) excavator and macerator in conjunction with a belt conveyor, 800 ft. long, supported on caterpillars. In the "hydrotorf" process, which Professor Purcell had examined last autumn at Schwaneburg in Oldenburg, high-pressure jets of water were used to wash the peat from the bog into large sumps; the product was probably not superior to air-dried peat, but the machines could be used on bogs containing much timber and roots, and the system was applicable to wide-spreading and drying grounds.

As regards utilisation, the 3,000 horse-power gas producer plant at Schweger Moor was now worked with coal (not peat). But Denmark had, in 1921, obtained satisfactory results with a Diesel motor plant at Haslev, and the Wiesmoor plant of the Siemens-Schuchert Company, erected in 1908, had steadily increased its capacity. The experiments of the Fuel Board with peat carbonised in Glover-West vertical retorts were certainly encouraging as to gas yield and by-products. In view, also, of the work done in Canada and Australia, Professor Purcell hoped for an expansion of the peat industry like that of the German brown coal industry. The report in question also referred to Ireland.

In the discussion Mr. K. B. Eller said that Mr. Purcell's conservative estimates of the peat resources of Sweden and Russia appeared too low. Mr. Haanel referred to the noteworthy work done in Canada, where Messrs. Peco Ltd. had perfected the Ekenberg process. Mr. Th. van Herson emphasised the importance of combining peat winning with land reclamation. Professor Purcell quite agreed, also as to the importance of small peat-coke gas-producers for lorries.

Two papers on oil and oil shales were then taken. The paper by Mr. C. J. M. Milo, of Holland, dealt with "Oil Refining" and cracking generally. Mr. Sven V. Bergh, of Stockholm, described his "New System of Oil Production from Swedish Oil Shales," explaining that Sweden had big deposits of oil shales, especially in the central and southern portion, near Kinnekulle and Nerike, and that the 5,000 million tons of shales contained only 4 to 7 per cent. of oil which could not be extracted. In the last three years new kilns for extracting the oil by means of superheated steam (20 per cent. of the shale weight) for 30 minutes had been developed, and a large plant was being erected at Kinnekulle. The internal dimensions of the units were 1·8 ft. by 3·9 ft. by 10 ft. high. The crude oil obtained gave gasoline and a heavy fuel oil.

The last two papers concerned two novel utilisations of wood waste. Mr. Otto Nordström of Sundvall, described in his paper on "Saw-Mill Waste in Sweden," the drying towers which he has put up in the Enqvist pulp mill at Tammersfors, Finland. The towers, of 70 cub. m. capacity, he stated, consisted of two slightly-conical shells of sheet iron, in the space between which the wood, raised by buckets, was allowed to sink down slowly; the tower was encased in brickwork and concrete. The inner cylinder was covered on the top and formed the end of the flue; a fan forced the gas (from the furnace) into this flue and further through perforations in the shell radially through the wood waste. A regulator of the Arca type adjusted the temperature of the ingoing gas to the moisture of the wood.

In the second paper on "Power from the Wood Waste of the Swedish Forests," Dr. H. von Eckermann explained how he generated gas for the power station of the Ljusne Sawmill and Iron works, on the Baltic, 250 km. north of Stockholm, from the undried wood waste directly as it came to the works, obtaining suction gas and tar. The 4,400 h.p. plant had been in operation for seven years. There was no coal during the war and no time for harnessing water-power. He, therefore, designed his heavy sheet iron generators, lined with fire bricks and provided with stationary grates. There would always be plenty of wood waste and tree stumps, though the law did not allow of cutting down more timber than was replanted; the high value of the tar had given him a profit of ½*d*. per kw.-hour, with power free, and enabled him even now to obtain his power, including interest and depreciation, very nearly as cheaply as water power.

Two papers originally on the agenda not having arrived in time, the Section terminated its deliberations on Friday morning.

SECTION D 1.—STEAM POWER PRODUCTION.

This Section of the conference met on Thursday morning the 3rd inst. under the presidency of Mr. W. H. Patchell. The papers to be dealt with were for the purposes of discussion divided into three groups.

In the first group was a paper on "Steam Power Production: General Review of Current Practice." having as its authors Mr. P. Junkersfeld and Mr. Geo. A. Orrock. The paper dealt mainly with American practice. It was stated that on January 1 last the total rated capacity of central stations in the United States was 22,895,000 k.v.a., of which 7,390,000 k.v.a. was provided by water power and the remainder by steam. The largest central stations had a capacity of 350,000 kw. and plants designed for 500,000 kw. to 600,000 kw. were now under construction. Some 650 to 1,000 tons of condensing water were required, it is stated, per ton of coal burnt. Pulverised coal on one system or another was being used at a number of the largest stations, the fuel being blown into the furnace from a bin. Where mechanical stokers were installed the drive was generally electrical. Cinder catchers were fitted on the chimneys at five stations. Two-thirds of the stations were designed to be operated with a 29-in. vacuum and the remainder with one of 28½ in. A steam pressure of 400 lb. per square inch and a steam temperature of 720 deg. F., were considered as not involving special plant, but two stations using steam at 550 lb. steam would be put in service this year, and three to work with steam at 1,200 lb. per square inch will be in operation next year. The majority of American stations were said to have a 40 per cent. load factor.

The automatic stokers installed were fitted with clinker grinders and burnt up to 60 lb. of coal per square foot of grate surface, evaporating 7 to 11 lb. of water per square foot of heating surface. The furnace capacity averaged about 3 to 4½ cub. ft. per 10 sq. ft. of boiler heating surface. The pulverised fuel plants were found to give high continuous efficiency and worked well with low grade fuel. The coal was prepared in a separate building and fed to bunkers at each boiler. The furnaces had air-cooled walls and water screens to absorb the radiant heat and keep down the furnace temperature. The furnace volume provided is from 4½ to 6 cub. ft. per 10 sq. ft. of heating surface and a combustion ratio of 2½ to 4 lb. of coal per cub.

foot per hour was attained with an evaporation of 11 lb. per sq. ft. of heating surface. The calorific efficiency was higher than with automatic stokers burning the same fuel and the fixed changes are about the same for the two types.

Air preheating had been adopted in a number of recent power plants, and the gain in boiler efficiency had proved greater than had been estimated. This was due to the higher furnace temperature and the greater heat transfer by radiation. In order to take full advantage of this, boilers had been constructed with the side walls of the furnace made wholly of metal heat absorbing surfaces, the tubes constituting these forming a portion of the water heating surface of the boiler. Maximum rates of combustion had risen from 20 lb. per sq. ft. of area per hour in very early installations to as much as 50 lb. and about seven times as much work was being obtained out of some boilers as was the case in the earlier plants. The latter evaporated from 2 to 4 lb. of water per square foot of surface, the corresponding figures for to-day being 4 to 15 lb. Some of the stations now in operation were, over tests of several months, securing 1 kw.-hour for 18,000 B.Th.U. in the coal supplied.

A paper contributed by Mr. W. M. Selvey dealt with "Pulverised fuel for boilers." The author stated that the standard of fineness of pulverisation largely adopted in the States was that 95 per cent. of the product should pass through a 200-mesh screen and 85 per cent. through a 100-mesh, but this standard was not suitable for all classes of fuel. He quoted Mr. A. C. Raymond to the effect that with bituminous coals none of the particles should be too large to pass a 50-mesh screen, and with anthracites the 50-mesh should be replaced by one of 80. As regards the question of drying, the author stated that a standard specification was that the coal should be dried down to 1 per cent. of free moisture, but he considered that a doubtful one to work to. Apparently about 1·3 per cent. of the fuel had been expended in drying the coal, but this could now be effected by waste heat from the flue gases. The author expressed the opinion that we were likely to have more trouble in this country from readily fusible ash (which fluxed the furnace linings) than was encountered in the United States. The burners now used were very simple. Where the "storage system" of using pulverised fuel was adopted, the plan followed was to provide a small quantity of injection air which carried in the fuel, and this was surrounded almost immediately by a proportion of the secondary air amounting to about 20 per cent. to 30 per cent. of the total. The remainder was provided by the pull of the chimney stack. With the "unit" system practically the whole of the necessary air was supplied at the burner. Injection velocities were kept as low as possible and large combustion chambers used. These had in fact a volume equivalent to 150 per cent. of that occupied by the boiler proper. American designs were based upon the consumption of so much coal per cub. ft. of combustion space. This might amount to from 1 lb. to 2 lb. of coal per cub. ft. per hour, and it was hoped to increase the latter figure to 3 lb. Direct impingement of the flame on brickwork could not be permitted unless the latter were cooled. This was done by adopting a cellular construction and passing through the cells the bulk of the secondary air. This is supplemented by what was popularly known as a "water screen." Recent work had been directed to securing shorter flames which would facilitate the abolition of brickwork.

Dust which deposited on the tubes was, in American practice, easily removed by soot blowers, but the author doubted whether this would prove to hold with English fuels. Very efficient combustion was secured, the spent gases analysing 15 per cent. to 16 per cent. of CO_2. The amount of these to be dealt with was correspondingly reduced, and very lower temperatures were attained. Boiler efficiencies approached 90 per cent.

The paper by Mr. L. C. Harvey discussed "The National Economic Power of Solid Fuel in Relation to its Scientific Utilisation." In this paper the author contended that the industrial prosperity of Great Britain must be built up on the foundation stone of coal distillation, and that the use of pulverised fuel would be a principal factor in the achievement of success. By pulverisation lower grades of coal could be successfully used, and it should be quite unnecessary for any country which possessed such coal to import much of the better qualities from overseas. As matters stood to-day 90 per cent. of the cost of the coal was lost. Each million tons of raw coal now burnt on the domestic hearth or under power-house boilers, could provide 20 million gallons of liquid products containing 2½ million gallons of motor spirit, and should also supply 15 million lb. of sulphate of ammonia. To-day we imported foreign oils to the value of 45,000,000*l.* yearly, whilst, with other arrangements, we could be self-supporting both as regards liquid fuel and motor spirit.

The author claimed that one result would be a saving in our national expenditure of 100,000,000*l.* per annum. By low-temperature carbonisation a smokeless fuel could be produced, containing only 8 per cent. of volatile matter and (after washing) only 0·5 per cent of ash. For domestic purposes this was required in lump form, and this presented no difficulty. For industrial purposes, however, a semi-pulverised fuel was all that was needed, and could be more cheaply supplied. This industrial smokeless fuel would weigh about three-quarters of the raw coal from which it was produced, and would analyse about 73·6 per cent. of fixed carbon with about 13·7 per cent. of volatile matter and 12·7 per cent. of ash. The adoption of the process should, the author stated, yield an increased profit of at least 1*l.* per ton of coal as mined. With hand-fired boilers efficiencies of as little as 40 per cent. had been recorded; with mechanical stokers this figure was raised to from 70 to 80 per cent., but the capital and maintenance costs were high. Producer gas firing was effective, but for efficiency costly regenerator chambers were required. By firing with pulverised low-temperature coke the deficiencies of mechanical stokers would be avoided, and the fuel was suitable both for low and high-temperature furnace work, when the presence of fine ash was not objectionable.

Pulverised fuel was now used for iron and steel making in Belgium, France and the United States, and had effected large economies in fuel.

In the ensuing discussion Mr. C. H. Merz drew attention to the necessity of preventing excessive wear and tear in the boiler furnaces, and, in supplementing his paper, Mr. George Orrok stated that at Hell Gate the brickwork had required practically no repairs in about a year's working. To-day over 19 lb. of water could be evaporated per sq. ft. of heating surface and at a rate of 4½ lb. per sq. ft. An overall efficiency of boiler, superheaters and economisers, equal to 91 per cent., could be obtained. Even on very high power tests an efficiency of 78 per cent. was secured. They hoped in future to attain an evaporation of 23 to 24 lb. per sq. ft. of boiler surface, which with some of the smaller tube boilers might be increased up to 28 lb. At Hell Gate the furnaces were steel lined on 3 sides, the other being brickwork, and were thus closely approaching to the locomotive firebox, though they secured a little better circulation. The cinder catcher to which he had referred in his paper collected 97 per cent. of the flue dust. If they adopted pulverised fuel they would put some form of dust collector in the stack. Mr. Harvey said that it was he who interested Mr. John Anderson in pulverised fuel, and had led the latter to adopt it for central station boiler working. Present-day methods of handling this material were perfectly safe, and there was now no difficulty with furnace linings.

A paper entitled "Fuel economy and the Measurement of High Temperatures" was contributed by Sir Robert Hadfield, F.R.S. In this the author emphasised the advantages of accurate measurements of temperatures both in boilers and furnaces. He said that for routine work on large installations the thermo-couple type of pyrometer was the most satisfactory. Boiler efficiencies would be increased by higher furnace temperatures and the difficulties connected with such might be mitigated by the use of a new steel due to a group of French metallurgists, which was now being manufactured by the author's firm. This material was less expensive than the nickel-chromium steels.

It was practically non-scaling up to temperatures of 1,050 deg. C. or more, and resisted, moreover, the sulphurous products of combustion. It had a high strength and tenacity even at 900 deg. C., a temperature at which the tensile strength of ordinary steel was negligible. It had been used in the cast state for recuperator tubes and carbonising boxes, and as forgings for the valves of internal-combustion motors, steam fittings, turbine blades, and many other purposes. In some supplementary remarks on his paper Sir Robert stated that at a temperature of 900 deg. C the material had a tensile strength of 15 tons per sq. in. as against 33 tons at 700 deg. C. Included with the paper was a colour chart which was based on experiments in the author's works and showed the colours corresponding to different temperatures. It had been found that by the use of this chart the temperatures of metals and furnaces could be determined within about 15 deg. C. for temperatures between 700 deg. C. and 1,400 deg. C. but inaccurate results would be obtained by a colour blind observer. The chart originated in the author's purchase of Turner's painting of Mount Vesuvius in eruption, and a comparison between the colours in this picture and those of the chart indicated that the temperatures in the eruption in question varied in different parts from 600 deg. C. to 1,400 deg. C.

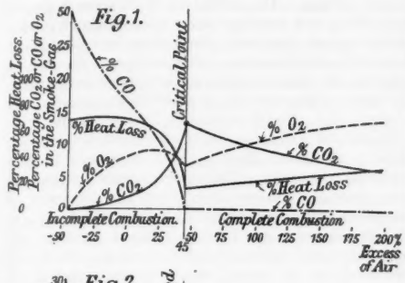
In a paper on "Coke as a Fuel for Steam Raising," Mr. E. W. Nichol drew attention to the fact that we had to import very large quantities of oil for use as liquid fuel or as lubricants. The number of motor vehicles now registered in this country was 978,000, and we were dependent for 60 per cent. of our supplies of petrol upon the exportable product of the United States and Mexico. In the former country there were over 14½ million motor vehicles in service, as against about 7½ million in 1919, and the number in Mexico was rapidly increasing. The average annual consumption of a motor vehicle was, the author stated, about 350 gallons. The total petroleum production of the world was estimated at 118 million tons annually as against 1,500 million tons of coal. The author held that demand would soon overtake supply, although new fields discovered in California, Texas and Oklahoma had again led to an abundance and comparative cheapness of petrol. In spite of this, however, the United States were now producing from coal 70 million gallons of benzol annually. Our maximum production of this alternative fuel was 26,400,000 gallons in 1918, but to-day we produced only a little over 11 million gallons of benzol. If all the available spirit were recovered from coke oven and town gas, it would amount to 46 million gallons, whereas our total consumption of motor spirit was about 350 million gallons. Hence, to improve our native supplies, it was imperative to distil a much larger proportion of the coal raised. This would also make available much low-grade coal now unutilised. Of the 189 million tons of coal we now used for fuel some 139 million tons are burnt in the raw state; if this were replaced by coke, our native supply of liquid fuel would be enormously increased.

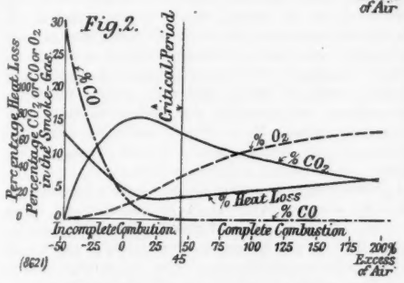
Mr. Olaf Rodhe, of Stockholm, contributed a paper on "Complete and Incomplete Combustion with reference to Combustion Economy." In this paper the author pointed out that the most important loss of heat in boiler operation was that carried away up the chimney stack. Hence, it was important to reduce excess air to a minimum. It was often assumed that the waste up the chimney stack could be determined from the CO_2 content, but he wished to point out that this might be most misleading, and might lead to waste of fuel. This would be clear on reference to the diagram, Fig. 1, on the next page, which showed the CO_2 content with various proportions of air when the fuel used had the following analysis:

C	80
H	4
S	1
O	9
Nitrogen	1
Moisture	4
Ash	1

The curves showed the variation of CO_2, O_2 and CO, and the heat loss, assuming a leaving temperature of 330 deg. C. With this coal, which was a very hard quality, complete combustion required an excess of 45 per cent. of air, and the corresponding proportion of CO_2 was 13 per cent. With either a larger or a smaller quantity of air than this actual

value, the heat loss was increased. With a softer coal, the critical condition was less sharply marked, as indicated in Fig. 2, and with this coal the heat



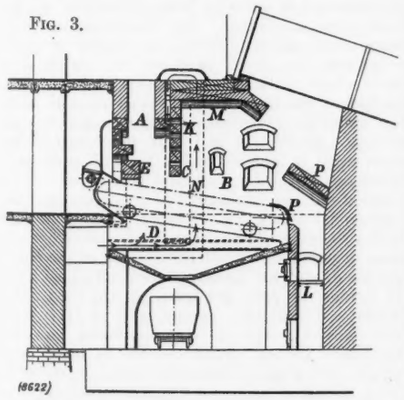


loss varied little over a considerable range, and good economy could be obtained even with 1 per cent. or 2 per cent. of CO in the waste gases.

A paper on "Le Foyer Système Combiné 'puitgrelles à chain' pour la Combustion de la Tourbe" was contributed by Prof. T. Makariew, and described methods of burning peat which had been successfully used in certain Russian power stations. The arrangement consisted of a self-feeding furnace combined with a chain-grate stoker, and it was stated that in this way all difficulties in the burning of peat under boilers had been surmounted, even when the fuel contained 40 per cent. of moisture. The fuel was progressively dried, gasified, coked and burnt. A sectional view is reproduced in Fig. 3.

Here A represents a hopper into which the fuel is tipped. The chain grate is shown at N, and the combustion chamber at B. The peat is dried by air entering through openings in the wall

FIG. 3.



E, and the gas produced passes into the combustion chamber by similar openings in the wall C. The dried peat falls on to the chain grate and is carried forward below the combustion chamber. The clinker formed is discharged over the scraper P. As installed at the fourth municipal power plant at Petrograd, an efficiency of 76 per cent. was attained, and the evaporation reached 11 lb. per square foot of heating surface. The walls C and E lasted four months without repairs and the chain grates longer than with coal. The arrangement is being adopted for other Russian plants now in course of erection.

In the discussion on the foregoing papers Mr. Brownlie laid stress on the importance of arranging some international system of boiler testing, so as to make records comparable *inter se*. The speaker had tested during the last 15 years 1,513 boilers, and the average efficiency was only 58 per cent., and from published records he thought matters were even worse in Germany and the United States. At present millions of tons of coke breeze were being thrown away, although with suitable arrangements it could quite well be used for boiler firing. Mr. Kilburn Scott and Mr. Emmott both drew attention to the probable utility of the new steels described by Sir Robert Hadfield.

A third group of papers was then taken. These described in the main modern Continental practice. A paper entitled "Heat Economy in Austria" was contributed by Dr. J. Tomaïdes, who stated that under the title of Gesellschaft für Warmewirschaft a society had been instituted in Austria with the object of utilising fuels and sources of energy with the greatest economy. Amongst other steps taken to this end was the provision of continuation courses for stokers. The committee concerned themselves with the economical domestic use of fuel as well as with the industrial use. A complete survey of Australia's resources was being made, and much general research work was in progress.

Mr. B. M. Gerbel contributed a paper on "The Reciprocal Utilisation of Waste Energy," which we reprint elsewhere. It described methods of combining the requirements of industries which require power and those which require low-temperature heat. In Vienna it was stated that the central power station already collects surplus energy from a number of industrial plants.

In a paper on "Outstanding Features of Swedish Practice in Steam-power Production," Mr. H. A. Lundberg described the use of Ruths' high-pressure steam accumulators to equalise loads on central stations, and also the adoption in service of steam pressures of from 850 to 1,400 lb. per square inch. We shall reprint this paper in an early issue.

A paper describing "German Practice in Exhaust Steam Engineering" was contributed by Mr. H. Treitel. In this paper the author described the wide adoption of back-pressure turbines where the exhaust was required for heating purposes. In one case the turbine developed 4,200 kw., taking 93,000 lb. of steam per hour, which was exhausted for heating purposes at about 21½ lb. per square inch. Where the demand for power at times exceeded the demand for exhaust steam "bleeder" engines or turbines were installed. Some of the latter had a rated capacity of 12,000 kw., and in fact 43 per cent. of the turbines of this size or less supplied by German makers during the past five years were of the bleeder type. In most cases it was necessary to provide that the steam withdrawn for heating purposes was of constant pressure. Turbines which in winter delivered for heating purposes all the steam that could be bled were operated during summer with a condenser. So far had the use of this combined system of power and heat production gone that in Germany turbines for industrial purposes were only exceptionally of the ordinary type. The linking up of power stations had made considerable progress. Thus, in one area six pits each had a power station, and were connected up to a single high-tension main, the aggregate power thus connected amounting to 20,000 kw. In this way electrical power was provided to 300 villages and towns. The upper limit of boiler pressure was now 35 atm, and Ruths' accumulators were provided to equalise fluctuating demands. These had been installed in many places, and could be provided for a peak of an hour's duration or more. In concluding, the author stated that expert advice on heat economy was more and more in favour, and that the advantage would be reaped when economic conditions became steady.

In the ensuing discussion Mr. George Orrok claimed that it was not profitable for a manufacturer to instal power plant even if he required steam for heating purposes. A manufacturer turned over his capital six or eight or ten times a year, whilst a power plant only turned over its capital once in six years. It was therefore, he considered, more profitable for the manufacturer to invest his money in his business and to purchase his power from outside. Dr. Enström said that the Ruths accumulator had been developed in Sweden owing to the fact that as all fuel had to be imported fuel economy was imperative. Hence arose combined systems of supplying both heat and power. As the maximum demand for both did not arise at the same time, some form of regulator was necessary, and the difficulty had been met by the introduction of the Ruths accumulator. These also were advantageous in connection for the steam power reserve provided for the hydro-electric systems. Mr. Klingenberg said that Mr. Orrok's claims held good only in the case of small plants.

At the afternoon meeting of Section D, the chair was occupied by Dr. A. F. Enström. The whole of the papers available were treated as a group and discussed together.

A paper on "Steam Generation" was contributed by Sir James Kemnal. It was to some extent historical. The author traced the growth of steam pressure and forecasted the proximate adoption of pressures of 500 to 1,500 lb. per sq. in., superheated up to 750 deg. F. With the latter a thermal efficiency, coal to electricity, of 30·8 would be realised, which was comparable with the efficiency of a Diesel engine. The paper contained illustrations of the type of boiler proposed for these high pressures by Messrs. Babcock and Wilcox. For pressures of over 750 lb. the drums would be seamless and probably be multiple. Where high steam pressures were adopted it became necessary to free the feed from air and carbonic acid, and one type of de-aerator was illustrated in the paper. The author claimed that it was now practicable to attain efficiencies of 90 per cent. in steam generating plant.

A paper on "Steam Generation at Extra High Pressures" was contributed by Mr. Viktor Blomquist. In this the author stated that by increasing boiler pressures from 20 to 30 atmospheres about a 5 per cent. increase in the thermal efficiency of the prime mover was obtainable, whilst if the pressure were raised to 100 atmospheres the improvement would be 20 per cent. He described briefly an extra high pressure boiler in which the tubes were kept in rotation so as to keep the water in contact with the walls by centrifugal force.

A second paper on the same subject was contributed by Mr. O. A. Wiberg. This was entitled "High Pressure Water Tube Boilers." In this the author laid stress upon the necessity for very efficient circulation of the water, and described a boiler which had been used at the "Stal" works since 1920. This operated under a pressure of 600 lb. per sq. in., the steam temperature being 750 deg. F. On test it had given an overall efficiency of 87½ per cent. We shall reprint an abstract of this paper in an early issue. Mr. W. S. Munroe was the author of a third paper on the subject. This was entitled "The Use of Steam at High Pressure and High Temperatures in Central Stations." The author recalled that at the Philadelphia Exposition of 1876 the Corliss engine exhibited, which supplied the power for the whole of the machinery and was the largest constructed up to that time, ran on 30 lb. steam. It developed about 2,000 i.h.p. The pressures and temperatures now practicable were limited by the properties of the materials available, and the paper contained curves showing the fall in the strength of steel at high temperatures. It emphasised the fact that these did not embody long time tests and suggested the possibility that long continued baking, even at temperatures of only about 700 deg. F., might show a falling off in the strength which was not apparent in ordinary tests. The author described briefly the Crawford Avenue Station of the Commonwealth Edison Company at Chicago. Three turbine units had been ordered for this station, one rated at 50,000 kw. from Messrs. C. A. Parsons and Company, Limited, one of 60,000 kw. from the General Electric Company, and one of 50,000 from the Westinghouse Electric and Manufacturing Company. The Parsons unit would consist of three separate turbines, *viz.*, a high-pressure turbine running at 1,800 r.p.m., an intermediate pressure turbine running at the same speed, and a low-pressure turbine running at 720 r.p.m. All three turbines were single flow. The General Electric set would consist of two units in series, the high-pressure section driving an alternator of 17,000 kw. at 1,800 r.p.m., whilst the low-pressure section will run at 1,200 r.p.m. and drive a 43,000 k.w.

alternator. The machine was single flow throughout. The Westinghouse unit would consist of a high-pressure and intermediate section on the same shaft, driving a 20,000 kw. alternator at 1,800 r.p.m., and a double flow low-pressure turbine running at the same speed, and coupled to a 30,000 kw. alternator. Parsons' blading would be used throughout but the "Baumann multiple exhaust" would be used at the exhaust end of the low-pressure machine. The condensers would be of the vertical type, in part because of the large amount of sediment present in the circulating water. The boilers would supply steam at 550 lb. per sq. in., and intermediate superheating would be used. Capital costs, the author stated, were little different for high-pressure stations than for those at which the pressures were more normal.

A paper on "Recent Practice in Steam Generation in the United States" was contributed by Mr. D. S. Jacobus. This dealt with certain recent installations there, giving dimensions and area occupied. In these efficiencies had been enormously increased, owing to the introduction of economisers and air pre-heaters. In one case a working pressure of 1,200 lb. per sq. in. had been adopted, and in others boilers capable of producing 250,000 lb. of steam per hour had been installed. A characteristic feature was the increase in the size of the furnaces which had been necessitated by slag difficulties. The large boilers could be operated with about the same staff as was required for smaller ones, so that labour costs were correspondingly reduced. Furnace walls were air cooled, and special attention was paid to securing good circulation. The author thought that in the future still larger units would be erected, and makers were now prepared to guarantee 300,000 lb. of steam per hour from a single boiler. It would be possible, he said, to operate boilers without a steam or water drum, but for this to be practicable the feed pumps would have to be absolutely reliable.

A paper on "The Influence of High-Pressure Steam on the Design and Economy of large Steam Boiler Plant with special reference to Boiler Plant for Electric Power Stations" was contributed by Dr. F. Münzinger. In this the author stated that recent research had shown that the quality of boiler plates fell off near the edges; and had also shown that ageing and recrystallisation of the plates might occur. This was a serious matter as no indication of the danger was afforded by the customary static test. For extra-high pressure boilers a 5 per cent. and a 3 per cent. nickel steel had been developed at the Krupp works. These showed higher tensile strength and higher yield points than the ordinary steels at temperatures now met with in boilers. Costs could be reduced by adopting the Ruths steam accumulator and correspondingly diminishing the water space provided in the boilers. It was now quite practicable to construct a steam operated station with thermal efficiencies closely approaching that of the Diesel engine.

Mr. W. L. R. Emmet contributed a paper on "Power from Mercury Vapour," in which he described the remarkable plant he has erected at the Hartford Power Station. We hope to publish this paper in an early issue.

In the discussion Mr. Brownlie drew attention to Trevethick's pioneering work on the raising of boiler pressures. Whilst admitting the progress made in the adoption of high pressures and temperatures, it should be observed that at the best over 60 per cent. of the heat was still thrown away and he suggested that it would more profitable to direct attention to minimising this, than to further developing the movement towards higher pressures. Mr. Wade said that a very large proportion of the total steam was generated in the lower rows of tubes, and suggested that more uniform results might be secured along the lines proposed by the late Professor Nicholson, by increasing the velocity of the gases over the later rows of tubes. As matters stood he knew of no water-tube boiler in which the gas velocities did not diminish as the distance from the furnace increased. Mr. George Orrok recalled the remarkable experiments on high-pressure steam made by the late Jacob Perkins. He also observed that we seemed to have got nearly to the limit of efficiency in steam generation, which, under favourable conditions, was as high as 92 per cent. on test, and had averaged over 80 per cent., for long periods. He doubted whether it would be possible to obtain an efficiency figure of 94 per cent. so that the limit was practically already reached. With respect to Mr. Wade's remarks he would say that in most water-tube boilers the gases were speeded up over the last rows.

Mr. Rosenkrantz said that a boiler erected at the Alleghany power station could supply 400,000 lb. of steam per hour. The furnace was 6 ft. high, 7 ft. 4½ in. between side walls and 30 ft. deep. Mr. Patchell claimed to have originated the movement towards larger steam generating units when 30 years ago he supplied a 4,000 kw. generator from a single boiler. He showed this to Mr. Dow of the Stirling Boiler Company, who forthwith took the matter up in America. He questioned the advisability of using alloy steels in high-pressure boilers. The high-pressure boilers at the Trenton Channel station had drums 4 in. thick, which were hollow forged from a 200-ton ingot. He had been struck by the steels shown that morning by Sir Robert Hadfield, which retained considerable strength at 900 deg. C. He hoped they might prove suitable for boiler plates. Mr. Kilburn Scott suggested that trouble might arise from free hydrogen, which had made it necessary to use carbon-free material for the synthetic ammonia process. Mr. Emmet expressed his interest in the new steels described by Sir Robert Hadfield, since in his mercury vapour boiler they approached the temperature at which ordinary steels became unreliable. He considered the mercury vapour system applicable elsewhere, and that it might be adopted even on board ship. He thought that an enlarged demand for mercury would increase the supply without any great increase in the price. He suggested that the system was less complicated than the arrangements adopted at Chicago. Mr. Ferguson, speaking as the engineer in charge of the Hartford Station, affirmed that his experience with the mercury vapour turbine had been most satisfactory. Fourteen per cent. of the total output was derived from the mercury-driven unit. Mr. Carnegie having been engaged on the design of the Parsons' 50,000 kw. unit for Chicago, said that he had found the problem sufficiently difficult without the complication of an initial mercury vapour stage, but Mr. Emmet did not agree with this. Mr. Samuelson said that it was difficult to get materials to stand both high pressure and high temperature but that the mercury vapour system avoided this, as the pressures were low.

SECTION B.—WATER POWER PRODUCTION.

Mr. Arthur Surveyer, President of the Engineering Institute of Canada, occupied the chair in Section B—Water Power Production—on the afternoon, Thursday, the 3rd inst., when the general papers were dealt with. In all, twenty-five papers were discussed, of which four each were presented on behalf of Sweden and Spain, three by American delegates, two were submitted by Great Britain, France, Austria, India and Germany, while Italy, Russia, Canada and the Dutch East Indies each contributed one.

Of the papers submitted by British delegates the first was by Mr. W. J. E. Binnie, who dealt with "Problems Relating to Run-off, Storage, and the Allocation of Catchment Areas in Great Britain and Ireland." The author pointed out first that in the absence of stream-gauging records, it was necessary for engineers, in considering water power schemes, to fall back on other means. These were available in the rainfall records, which were now procurable for a considerable period for this country, and, with a knowledge of evaporation, might be used as a very useful guide in making estimates of available flow. The character of the basin had to be taken into account. Where no opportunity existed for storage, stream gaugings in dry weather were of supreme importance. The balancing effect of a catchment area was in some cases very considerable if its size was great. In two basins like that of the Alwen (10 square miles) and the Severn (1,960 sq. miles), in an average year it would be possible to develop 61 per cent. and 80 per cent. of the discharge into power, respectively. Conduits to conduct supplies into storage could not be made economically to accommodate the maximum flood discharge and the most economical size had to be determined. In this country reservoir capacities were calculated on the run-off of the three driest years. It was seldom economical to provide for longer periods. The allocation of supplies required controlling and putting under some authority with knowledge of what had gone before instead of being dealt with by temporary committees. The whole question of compensation water needed revision, as the present practice led to wasteful anomalies.

Lieut.-Col. C. M. Norrie's paper dealt with "Factors of Efficiency in Hydro-Electric Development" on broad lines without reference to any particular country. Thought in this connection was generally concentrated upon the efficiency of machines and other important points were lost sight of. Resources should be developed on the best lines from the national point of view, but if this involved, as it might, very heavy expenditure in the initial stages, the State should assist private enterprise in a commensurate manner, or the State might construct the heavy permanent works and recoup itself by selling water for power purposes. A national organisation for collecting data was most desirable. Most other countries now had them; Great Britain had no organisation of this kind. In localities where coal was the basic source of power it was generally found cheaper to conserve fuel by direct saving than by substituting water power. Where water formed the basic source the relative costs of energy permitted of the use of fuels only as auxiliaries. The advantage of the auxiliary plant was that it supplemented deficiencies in uncontrolled river flow, and acted as a stand-by in case of breakdown. The construction work of dams, canals, pipe lines, &c., other than mechanical and electrical equipment, represented 60 to 85 per cent. of the cost of water power schemes, pointing to the need for every economy in this direction. Complete preliminary investigation was essential. Future needs should not be anticipated in too great detail or it would be impossible to take advantage of improvements. Co-operation was essential so that full advantage might be taken of improvements in turbine and generator design.

MM. Arbelot and Dupin presented a joint paper dealing with hydro-electric power in France, while M. Maroger contributed a second. The first considered the development in France in three stages, viz., the first stage when power installations were isolated and self-contained; the second when the schemes covered the catchment areas; and the third when inter-regional compensation was adopted, the resources of one area being utilised to supplement those of another. The endeavour was now made, not so much to develop a constant demand, as to suit the power produced to the demand curve which could seldom be made uniform. The pooling of resources would become possible when the national transmission network connected all stations. Regulation had only progressed so far as to result in added complication with each additional development. Technical points were at the moment not so important as the economic and commercial aspect. M. Maroger pointed out that in France the individual companies would have to form groups for the better utilisation of the power produced, and for supplying distributing systems. In France the price per kw.-year had been abandoned in favour of a double tariff of (1) a fixed rate for kw., and (2) a proportional rate per kw.-hour. Groups would be able to interchange power, but a large electro-chemical or metallurgical industry appeared indispensable for the economical use of the resources of any large hydraulic group.

The necessity of supplementary steam generating stations formed the topic of a contribution by Mr. G. Motta (Italy). The author described how supplies in the Apennines were usefully supplemented in summer by connection with systems served by the Alps, but that the service was only effective in part. Storage could not be arranged in the Alps on a large scale, while if provided in the Apennines the head could only be low. In order to provide the maximum power therefor it was essential to develop water power to the greatest possible extent, and, even in Italy, to adopt thermal stations as supplementary sources for times of low flow. Such stations should be designed to cope with the maximum fluctuation. Thermal stations were

further valuable reserves in case of failure of the hydraulic plant.

Of four contributions from Swedish representatives, two were entitled "Recent Practice in Lake Storage and what the Storage means to Water Power Utilisation in Sweden," and "Recent Practice in Swedish Water Power Engineering." The first, by Mr. Gottfried Berg, described how Sweden was favoured in the matter of lakes which acted as regulators or compensators, which could be utilised with small expense to obtain a very large gain of power. The interconnection of installations made it possible to exchange power and in this way the best advantage could be taken of supplies. For good management, however, it was essential to be well informed on the variations of hydraulic conditions as well as those of demand, and these points required very careful study. With complete lake regulation Sweden could develop the power she now obtained from imported coal. The other paper on Swedish practice referred to above was by Mr. A. Westerlind and dealt mainly with points of construction. As regards dams, the gravity section did not carry such confidence as formerly. Reinforced structures were being adopted with arch construction. At Harsprånget the proposal was to build a reinforced concrete arch dam of 300 metre span. Ice pressure did not exceed 30 tons per metre run for a thickness of 1 m. of ice. It was probable that mechanical means would be developed for passing timber, so as to avoid the loss of water in chutes. Loss of head was reduced in channels, &c., by smoothing off and lining with concrete. Channels cut through shingle were lined with clay. The rock was solid, and unlined conduits were suitable. The largest power tunnel was at Trollhättan, with a sectional area of 85 sq. m. Turbines in open chambers were now used for heads of 20 m., as at Alskarleby, where the buildings were of reinforced concrete. Suctions and spirals were often lined with clinker. Surge tanks were adopted with pressure conduits and large suction chambers were provided. Screens were sometimes made so that the bars could be revolved. Roller dams, though expensive, were used for large openings, being easily operated in winter. The largest in Sweden were those at Forshuvudforsen with a diameter of 8·59 m. With control gates and sluices, the designs of grooves, rails and guides were being simplified. Sluice gates were now built with horizontal beams and convex faces. Roller carriages for sluices of the Stoney type were being abandoned in favour of four large rollers fixed to the gate. The seal was made at the sides by suspended tubes. Chains were giving way to cables for lifting. No trouble had been found with construction work in winter if suitable precautions were taken with concrete, and the work protected by temporary covering.

A general paper on the production of water power in Sweden was presented by Mr. A. Ekwall, who in reviewing present tendencies attempted to make a forecast as to future developments in that country. The greatest developments would be in connection with river regulation, which could be considered from the point of view of daily regulation, or weekly or yearly regulation. An installation involving regulation could produce 2½ times the amount of power provided by a scheme omitting all regulation. The remaining paper from Sweden dealt with the reliability of operation of hydro-electric plants. It was by Mr. K. E. Nylander and discussed the system of connection of the generators at different stations, the points insisted on with regard to generators, transformers, circuit breakers, &c., and finally the provision for fire fighting, tetrachloride *extincteurs* being adopted and fixed batteries of CO_2 bottles.

Mr. Diego Mayoral, in his paper on "Some Features of Modern Hydro-electric Developments," said that on Spanish rivers at altitudes less than 1,000 ft., though they had rarely to combat ice, a common trouble in more northern lands, they had to fight the obstruction of vegetable matter by strainer racks. Inexpensive movable racks were therefore necessary. Cracks in tunnels through rock had given trouble. It appeared that they were due to the compressions being greater than supposed. If the walls were considered for calculation to be elastic and of indefinitely great thickness the results were too optimistic. Gates and sluices of penstocks required great care in operation. Sluice and butterfly types should be replaced by modern balanced types. In Spain the natural resources were such as could be developed in medium and even small falls by units of great simplicity of construction and of automatic action. Discussing transmission, Mr. Mayoral said the Catalana de Gas y Electricidad S.A. of Barcelona, with 225 kilometres of overhead line and equipped for 130,000 volts at the supply end, had experienced no trouble during its life of five years. The separating wall between coils of transformers constituted weak points in three-phase units and their elimination was desirable.

In his paper on "The Regime of Flow of Some Spanish Rivers," Mr. Carlos Mendoza described the characteristics of some of the rivers in the centre and South of Spain from which the conclusion was drawn that these areas were not suited to the use of hydraulic power unless supplemented by auxiliary steam-power stations or unless great reservoirs were constructed to regulate the torrential discharges. Another paper presented by the same author dealt with the canalisation and utilisation of water power on the River Guadalquivir. The projected plan was the creation of a series of reservoirs at different levels obtained by eleven sluice gate dams, for the development of water power. The available horse-power was 61,800. The river was very torrential and without the reservoirs the power would only be 8,000 horse-power at the period of low water. State assistance would be obtained for part of the construction. M. José Orbegozo gave the fourth Spanish paper, in which he described the scheme for developing hydraulic power from two important groups of waterfalls in the basin of the River Douro. The continuous power available was 826,500 h.p., but it reached 1,068,000 in the winter. It was estimated this could be obtained and transmitted for a capital cost of £15,400,000.

Dr. Frederic Schaffernak, Austria, submitted a contribution on the "Influence of Large Water Power Installations on the Regime of Flow" and Mr. Eduard Suess gave a paper on "Rivers as Factors of Energy." Germany was represented by two papers—one on "The Development of German Water Power," by Mr. Krieger, and the other on "Water Power on Inland Waterways," by Dr. Gleichmann. Only in the southernmost parts of Germany in the Black Forest, in the portion of the Alps belonging to Germany, and in the areas crossed by rivers carrying water from these mountains did favourable conditions exist for water power development.

In India the needs of irrigation must be met by the erection of water storage accommodation, as was brought out by Mr. S. K. Gurtu, and water power schemes could be associated with this with profit. The total output of hydro-electric power in India was about 360,000 h.p., which could be increased enormously were storage dams erected. For use in slack seasons of irrigation an auxiliary steam plant would be necessary.

Mr. H. G. Acres, who contributed a paper on "The Generation of Hydro-electric Power in Canada," discussed many features of modern practice. Where store regulation was all that was required, simple stop gates were used; where frequent and rapid changes in flow were involved, counterweighted gates of the Stoney type were almost universal. When extreme low temperature was a factor it was common practice to bury the penstocks or to use wood stave pipes. For the protection of the inner system of waterways or pipe lines from the entrance of ice all entrance passages were given adequate submergence. From the standpoint of ice hazard it was necessary to provide as uniform and smooth a surface gradient from intake to forebay as possible, and to make the depth as great in proportion to width as the natural slope and scouring propensities of the overburden and the underlying solid material would allow. There was a marked tendency in Canada to use vertical turbines and generators for any size of installation.

Mr. Charles Keller, U.S.A., discussed "Power Development on Navigable Rivers," dealing first with the legal questions involved, and then with the instances where, during the course of improvements for navigation, attempts were made to preserve the incidental water power and to create conditions favourable to its economic development.

Mr. J. Willoughby Meares said that, in dealing with run-off from a catchment area, they were confronted with varying rainfall conditions. With the use of recorders it was possible to ascertain the intensity of rainfall and use it to determine the run-off from the catchment area. Col. Batty had referred to rock-filled dams in valleys as being suitable for water storage. Mr. Meares then described a case where an earthquake caused a block in a valley to a height of 1,000 ft. A certain amount of water passed through, but the level rose until full height was reached. Eventually everything was swept away. Had there been a divergence channel this need not have occurred. He agreed that valleys could be blown in, but the trouble experienced was that the water got over and destroyed these dams unless divergence channels were made.

Mr. W. J. E. Binnie pointed out what a disadvantage it was that the accumulation of water statistics was left in many places to private enterprise and thus the figures were not easily procured. The water engineers were left to depend for information on the rainfall records. The rainfall to run-off relationship was fairly close. A factor introduced for the month made the estimate approximate to the actual state. The question of what constituted an economic storage capacity demanded a great deal of consideration. It depended greatly on the natural conditions of the site. There were few rivers in England suitable for hydro-electric schemes, and storage was therefore essential. In the Highlands storage was obtainable economically, but every case had to be considered separately.

Dr. E. Tissot described the progress made in Switzerland, where coal was a large import and was very costly. Industrial expansion depended therefore on water power. He then described some of the Swiss installations. Mr. D. H. Thomson said that in this country few stream gaugings were made, and calculations were based on rainfall, making allowance for evaporation, &c. The minimum dry weather flow was an important factor and had no relation to drainage area or average flow. He cited a case in Devonshire where the dry-weather flow at an upper station was 8 per cent. of the average flow and at a lower place was found to be 33 per cent. of the average there. The explanation was geological. The rock was new red sandstone, in which cracks and fissures provided underground storage.

Mr. A. E. Kitson, Director of the Geological Survey of the Gold Coast, referred to the effects upon the run-off of cutting down trees in forested countries. A greater run-off was obtained when the forest was partly cut down. Other factors affecting run-off were the effects caused by insects creating caverns in the soil and the seasonal burnings of grass. Mr. Harold Armfield called attention to irregularities in the minimum dry-weather flow observed on the Wiltshire Avon. Mr. John R. Freeman, the author of a paper on a General Review of Current Practice in Water Power Production, then briefly surveyed the growth of size of units and the contributions of the various workers in the evolution of modern plant.

Mr. W. T. Halcrow described the Scottish water power development undertaken by the British Aluminium Company at Foyers, Kinloch Leven, and the proposed Loch Aber scheme. When the last scheme was completed 100,000 h.p. would be available there. A pressure tunnel 15 miles long and 16 ft. diameter would be driven through the rock, which had been found to be eminently suitable for the purpose.

The Chairman, in closing the discussion, referred to what has been done in Ontario, where 93 per cent. to 94 per cent. of the power was obtained from water. They had ice to deal with for two or three months every year at Niagara, but it was got rid of by a new type of intake designed after the performance of model tests. In this the important points were adequate submergence of the entrance passages and a low entrance velocity, not only to prevent vortices but to be less than the buoyancy impulse of the floating material. Canada had complete information regarding her running streams.

Two sessions of the Water Power Production Section B were held on Friday, July 4, under the

chairmanship successively of Mr. S. Klaumann (Norway), Director of the Norsk Aluminium Company, and Dr. Ed. Tissot (Switzerland), President of the Swiss Association of Electricians.

A paper by Oberbaurat Dr. Ing. Karl Innerebner, Austria, on "Recent Practice in Civil Engineering with Reference to Water Power Production" was taken as read. The author was concerned particularly with errors that became apparent on the completion of works, such as in tapping existing natural lake basins, the subsidence of the banks of natural lakes when their levels were lowered through their utilisation for water power plant, the construction of concrete dams, the use of pressure galleries and shafts, surge tanks and overflow channels from them and delivery pipes.

Mr. W. Blaser, Chief Hydraulic Engineer of the Government Service for Water Power and Electricity in the Dutch East Indies, read a paper on "Special Conditions of Civil Engineering Features of Water Power Development in the Dutch East Indies." It contained a summary description of hydrological, topographical and other conditions of the Archipelago which make standard constructions practically impossible and give rise to separate problems for almost every individual part. Systematic research on the possibilities of developing water power only began about ten years ago, and the previous hydrometric data which had been collected for the purposes of the Irrigation Services were imperfect. Almost all the hillsides were in a state of rapid disintegration and erosion. In Java almost all the mountains were volcanoes, some of which were still active, earthquakes were comparatively numerous, though generally not very heavy; evaporation was nearly constant throughout the year, and the rainfall was from about 2½ in. to 3 m. on average heights up to 8 m. on the tops of several mountains. The year was divided almost equally between dry and wet seasons, and in many parts the wet season fall was as much as 20 times as great as that of the dry season. Ten inches and more in 24 hours were not unknown, and floods might raise water levels by as much as 5 m. in an hour, washing down all sorts of material, from big stones to silt. Water rights for irrigation were so general that power development was practically impossible in the lower parts of rivers; hence power plants dealt mostly with relatively small quantities of water and what in the Archipelago were considered high heads (50 to 350 m.). Labour was cheap and tractable, but cement was expensive; stones for masonry were found in the rivers.

Mr. L. Mangiagalli, Italy, read a paper on "Recent Development in Dam Construction in Italy." In Italy a serious development of reservoirs began not much more than ten years ago. At the present time Italy was passing through a period of active growth both of her industry and her agriculture, and in the last ten years had constructed numerous reservoirs and dams mostly for hydro-electric purposes, but also for irrigation and the control of floods. Particulars were given of various types, from those situated at the foot of glaciers up to those at the highest levels. No special design of dams was followed generally, but the variety of circumstances was not so great as to compel the uncertainty and continued evolution of design that was necessary before the first modern French dams were built, and there was a considerable tendency to adopt the light types of multiple arch dams. Mechanical means were used freely in construction, owing to the great increase in the cost of manual labour and the need for rapid completion of extensive works. American machines for dealing with cement and concrete, either by elevators and subsequent gravity descent or with the cement gun, were particularly popular, and photographic and other technical control was used freely. Italy now claimed some of the largest reservoir works in the world. Thus the Tirso dam in Sardinia of the multiple arch type was 69 metres high, and the reservoir, which has already been working for more than a year, contained 460 million cubic metres and was 26 kilometres long. The Hone reservoir in Sicily, again, had a masonry dam with a capacity of 35 million cubic metres, and the waters of the river had been diverted from the south of the island to the north side to enable them to be applied to irrigation purposes.

Mr. Guido Ucelli, Italy, read a paper on "Recent Developments in Italian Water Turbines." As far back as the 15th century Leonardo da Vinci was trying to improve the old water wheels, and, while insisting, in a passage that the author quoted, on the need to consult experience in hydraulic matters before theory, went some way to anticipate modern principles of design. Since the war, practically all the turbines used in Italy were home-made, and designed specially for each plant. As far back as 1899 an Italian firm supplied two 3,000-h.p. Francis turbines for use at Niagara. The sizes built by Italian firms had continually increased till now 35,000 h.p. units were made, and still larger were being designed. Plants for heads of under 20 metres were used first, but Italy has no great watercourses and only small plains, so that large plant turbines to work with only a few metres head and extremely high speed were not required. Medium fall plants—20 to 200 metres—were frequent, and the maximum power was reached in high and very high falls of over 1,000 metres. For low falls the Girard and other impulse types had been abandoned completely for reaction types working in open chambers. Units were sometimes arranged tandem, enabling part of the runners to be out of work, so as to utilise water discharges when seasonally reduced. The use of draft tubes for low-fall turbines was extending, and sometimes the turbine shaft had even been placed above the service of the feed water, the entire fall being thus used in suction by means of a syphon. For the most part designers limit the specific velocity to about 500.

Though horizontal shafts were mostly preferred, some vertical shaft plants had been included, and one of 24,000 h.p. for the Velino plant at Terni was under construction. Designs with horizontal shafts include single wheel with single and with double discharge, two wheels each with single central discharge, and two wheels with separate discharges; the last being sometimes desirable to enable the work to continue when the volume of water was reduced, in the same way as with the tandem arrangement for open chamber turbines. A number of other designs were mentioned; the largest reaction units in Italy were three of 24,000 h.p. each at Velino of the Francis type running under 84-110 metres head at 420 r.p.m., with two wheels and a central discharge. Pelton type impulse wheels for heads of 1,000-1,500 metres represented about 40 per cent. of the total Italian power, both double or multi-jet turbines and multiple wheel turbines were used, running at a high number of revolutions. Great attention had been given to methods of controlling impulse wheels by causing deviation of the jets. The oil pressure governor now used generally in turbine practice for automatically proportioning power to load without affecting speed was itself an Italian invention made in 1900, and Italian firms had brought it to great perfection. In recent tests, carried out with a Pelton turbine at Venaus, the sudden cutting off of about 26,000 h.p. load only raised the speed from 500 revs. to 525, while the jet deflector acted so perfectly that the pressure gauge on the high-pressure conduit showed an almost imperceptible variation from the normal figure of 102 kg. Home makers were able to provide for the entire home needs of Italy in respect of turbines, and were anxious to increase their export trade. Their efficiency was shown during the war, when in the face of the utmost difficulties of supplies and labour, it was found able both to keep running all the existing turbines and provide new hydro-electric plants for war industries, then threatened anxiously by lack of coal.

The Verband der Deutchoesterreicher Maschinen Industrie (Austria) presented a report on "Progress in Mechanical Engineering with Reference to Power Production," which included observations not only on water turbines but also other elements of power production. A standard type for high heads was a Francis spiral which has been made up to 15,000 h.p. The highest head used so far was 250 metres. Most progress has been made in respect of speed, which has been increased to treble what was previously obtainable in the Francis turbines; a matter of special importance for Austria, which in the lower course of small and medium Alpine rivers have to deal with heads of 4 metres to 10 metres and volumes of water from 20 cubic metres to 80 cubic metres per second. This furnished the best field of application for high-speed propeller turbines. The first important plant with propeller turbines of the Kaplan type has been running at Siebenbrunn since 1923. The efficiencies down to one quarter full load have been most satisfactory, and designers need not anticipate any trouble with the type. The plant included two four-vaned propeller turbines with adjustable blades. Experiments and careful designing had enabled all cavitation troubles to be avoided. Two separate servo-motors, co-ordinated hydraulically by a cam, adjusted the stationary and moving blades so as to maintain the highest possible efficiency. The installation worked so satisfactorily that the design was likely to be standard in the Austrian Lower Alps. A special section of the report dealt with stop valves for water power pipe lines, in which the tendency of practice seemed to be to replace mechanical hand operation by hydraulic apparatus with protection against frost, to work without pressure compensation, and to provide for distant control, especially for closing, one type being an electro-mechanical relay releasing a hydraulically controlled weight. As auxiliaries to water power plants to meet either peak loads or shortage of water, low-pressure crude oil engines were recommended as against Diesels, on the ground that, though slightly higher in oil consumption, they were barely half the price of a four-stroke Diesel and cost much less for maintenance. Attention was also called to the several requirements of stop valves for superheated steam, and to the fact that as yet no valve had been designed to meet all of them. Particulars were given of methods of designing stationary standard Diesel engines which had resulted in a considerable reduction of prime cost.

A paper by Mr. Emilio Azarola (Spain) on "Mountain Side Canals," was taken as read. The many mountain streams in Spain and the dearness of other means of lighting had led to a considerable use of electric light in small villages. The use of high falls and reservoirs had obvious advantages, but the possible unsoundness of the bottom of the reservoir, the relatively high cost of construction and a legal difficulty apparently peculiar to Spain, had led to the more general adoption of mountain side canals for the supply of water power. These canals were constructed without realising their extreme sensitiveness to any motion of the ground and the considerable tendency of the sides of mountains to slip. Whether by the fall of material from above or its sliding from below with the consequent production of a leak, it was found necessary at the outset to line the whole of the bottom and sides of such canals with masonry; and even this was insufficient to provide for the effects of variations of temperature and for settlements under the pressure of water with the resulting longitudinal fissures. The paper described the several cases that had been found in practice and, after mentioning certain measures that tended to mitigate these troubles, recommended as the heroic remedy for all such difficulties the construction of covered or subterranean canals. With cover, which strengthen the structure by holding it together at the top, 30 centimetres thickness of earth was as a rule sufficient in Spanish climatic conditions to prevent the works from dilating or developing fissures, and at the same time the added strength given by the roof made it possible to use thinner walls. As against the cost of construction was to be set the lower price for way-leaves as compared with the cost of land for open canals. The most approved method was to use galleries, lining the wetted perimeter, but in compact rock only making good the fissures. Details were given of constructional methods for covered canals, as well as a system of metallic piping with flexible joints which enabled the pipe to follow any movement of the soil, and to sink at each joint by over 3 ft. without permitting leakage. The joints were jacked up to their original position from time to time.

Papers by Mr. Bo Hellstrom (Sweden), on "Recent Swedish Arch Dam Design," and by Mr. Arthur Powell Davis (U.S.A.) on "The Construction of Dams" were taken as read, and the former will be found on page 76 in this issue.

A paper was read by Mr. William Monroe White, (U.S.A.), on "Impulse Water Wheels." The

starting point of current practice was the invention and development of the Pelton wheel towards the end of last century. After outlining the fundamental principles of the construction of impulse turbines and the relation between the efficiency of modern machines and their specific velocity, the author discussed the action of the jet on the buckets, and the general conditions for efficient working, with examples from practice, including designs not only by the Allis Chalmers Manufacturing Company, with whom he is associated, but also by other leading manufacturers. In particular, he drew attention to the need for adequate bearings to take the enormous weight of the moving parts, and illustrated some forms of them. He also described various pressure regulators, both in systems of regulation by escaping water and by arrest of water, and gave and illustrated general descriptions of some important impulse turbine installations in the west of the United States. He believed that, though the efficiency of impulse wheels—at present about 82 per cent. to 83 per cent. —might be increased, it was not likely to attain that of Francis turbines, which in one example had reached 93·4 per cent. At the same time, although the Francis turbines were now made to develop 35,000 h.p. under heads of 850 ft., the simplicity and reliability of impulse wheels would prevent them from being displaced for heads of 750 ft. and upwards.

Mr. H. Birchard Taylor (U.S.A.), who is associated with the Cramp, Pelton and Harper and Taylor Companies, read a paper on "The Hydraulic Reaction Turbine," which will be found elsewhere in this issue.

Professor D. Thoma (Germany) read a paper on "Experimental Research in the Field of Water Power." Contrary to what appears in much German literature, all German turbine design had for a long time been based on experimental research and not on unaided theory, as were the earliest designs. The more important firms had long made a practice of delivering no turbine until a geometrically similar trial turbine on a smaller scale had been previously tested. Results had shown close agreement between the large and small scale trials, the few discrepancies having been traced to geometrical divergencies between the machines under comparison. This practice enabled the behaviour of large runners to be ascertained in advance with sufficient accuracy by the trial of small runners, the increase of efficiency through enlargement of dimensions being introduced as a correction according to Camerer's formulæ, which had been found fairly correct. The author had found a convenient method of experiment in the use of successive variations, sufficiently small to enable comparisons between the results to be made step by step, and progressively more favourable variations to be adopted as the basis of succeeding trials. In this method assistance was likely to be found from the practice of Dr. Lawaczeck of representing vane surfaces by an equation containing certain parameters, which were a convenient basis for filing and comparing the results. In recording results the author suggested the adoption of absolute coefficients instead of metric or English figures, and illustrated how they could be constructed. Attention was called to the trouble arising from too high a suction head, especially in leading to cavitation. In order to be able to use experiments, which could only be made on small turbines and low heads, for inferences to larger sized plants, careful account had to be taken of the bearing of the law of similarity on cavitation.

Dr. Franz Lawaczeck (Germany) read a paper on "Large Low-Head Water-Power Developments," which we hope to be able to reproduce in a subsequent issue.

In presenting his own paper on "Impulse Water Wheels," and that of Mr. Taylor on "The Hydraulic Reaction Turbine," Mr. White remarked that the experiments of which he had communicated the results had cost many thousands of dollars, and were put forward in the belief that for the common purpose of increasing the output of power, engineers of all countries should combine to exchange information, and collectively to produce what their countries have a right to expect from them. In the United States purchasers were sufficiently keen on obtaining the maximum output to be willing to incur any desirable expense in preliminary experiment, and as a result they obtained considerable efficiency. One purchaser, for example, paid 20,000 dols. merely to determine the best shape for a runner for a particular wheel.

Mr. Arvid Ruths (Norway) read a paper on "Ice Troubles in Norwegian Water-Power Plants," an abstract of which will be found elsewhere in this issue.

Mr. Cornelio Arellano (Spain) read papers on "The Protection of Industrial Canal Works from Debris and Brushwood" and "The Protection of Industrial Canal Works from Stones and similar Water-borne Material," which described and illustrated an arrangement of sluices, screens, and grating to prevent rubbish and brushwood from settling in industrial canals and gave particulars of certain installations in which they were fitted.

Mr. A. Frey Samsioe (Sweden) read a paper on "Measures taken in Sweden against Ice Troubles at Water-Power Plants." Swedish water-power plants were situated variously from the north part of the Arctic circle to a latitude of 56 deg. N. The ice trouble was worst in the middle and southern parts, where measures against ice were sometimes omitted on the ground of cost. Rapids above the power plant were always a source of trouble and must either be dredged or submerged, so creating a still-water basin extending some distance up the river. Failing this, anchor ice was likely to form on boulders in the river bottom, and might produce a formidable jam when it was loosened. When, moreover, water in the rapids was churned up with cold air a whole stream got saturated with ice needles, which produced a troublesome ice sludge. The latter mischief might occur even with still-water basins, should a cold storm occur before the still-water basin had been frozen over. Ice-sludge clogged screens, and as a rule fishery regulations prevented the screens from being moved bodily. Wood was preferable to steel, as ice did not fasten on it so rapidly. Where steel was used, electrically heating the steel bars of the screen had given good results, taking only 10 kw. for each one sq. m. area of screen, and wood insulation was quite satisfactory. Electrical heating was also used to prevent ice forming on sluices. Special radiators were applied for this purpose; 2 kw. per square metre (0·2 units per square foot) was sufficient to prevent ice from fastening even on the most exposed parts at a temperature of — 20 deg. C. Hot air from the generators might also be blown into recesses, or steam when the dam was located close to a factory where it was used. To avoid ice formation at the intake, this was covered by a shed heated with air from the generators. To keep the sluices working the moving parts were heated electrically. The valve was covered on the outlet side and hot air or steam introduced. Steel pipes and surge tanks were insulated. The danger of ice pressure against dams had been greatly exaggerated by neglecting the viscosity of ice. In Sweden it was usually sufficient to saw grooves in the ice above the dam, which were covered by branches and snow or by straw and manure.

Messrs. Arbelot and Dupin (France) presented a paper on "The Evolution of Opinion on the Control of Hydro-Electric Energy," in which they urged the importance in some districts of creating a sale for current during flood times by establishing adequate equipment for utilising flood water, increasing the load factor of existing works, putting a specially low price on the surplus current, and interconnecting systems of districts whose floods occur at different seasons. This would be possible only when all important power stations were connected to the national transmission network now under construction. For power stations with a fixed output, such as those that operate on the flow of rivers alone or tidal power stations, no such adjustment was possible. To regulate production according to demand, large seasonal reservoirs would have to be constructed. Surplus plant would have to be provided in the works that these reservoirs supply, and thermo-electric works would have to be increased. In the view of the authors a really efficient solution of these problems can be reached only by placing the development of power more in the hands of a single authority.

Some discussion took place on several of the papers, in the course of which speakers from various countries contributed details of their experience.

SECTION D.2.—STEAM UTILISATION.

On Friday morning, July 4, the members of the Conference assembled in No. 2 Hall, under the chairmanship of Mr. John W. Lieb, to discuss four papers relating to steam turbines, namely, "Steam Turbines," by Sir Charles Parsons; "Steam Turbines for High Pressures," by Mr. C. F. Stork (Holland); "Extra High Pressure Steam Turbines," by Mr. V. Nordström (Sweden), and "Steam Turbines and Condensing Equipment," by Mr. Francis Hodgkinson (United States). We print the first and second of the above papers in abstract elsewhere in this issue, and shall deal later in the same manner with the important paper by Mr. Hodgkinson. At the present time it must suffice to say that Mr. Hodgkinson's paper deals with the tendencies of American practice with regard to steam turbines and condensers. The author, as is well known, holds the position of Chief Engineer to the Westinghouse Electric & Manufacturing Co., of Pittsburg, one of the principal manufacturing firms in the United States, and is, therefore, written with intimate knowledge of American practice, particularly concerning the reaction type of turbine. The subject matter is limited to large turbines and condensers as used in central station work, and no attempt is made to deal with details of lubricating, regulating, and other ancillary apparatus.

The author first shows how the difficulties of providing an adequate area for the passage of the steam through the low-pressure end of the turbine have been surmounted by different designers and firms. Double-flow on multiple steam paths, in the low-pressure end, and compounding the turbine by using two or more separate cylinders, frequently driving generators at different speeds have all been successfully adopted. The Baumann multiple exhaust, of the Metropolitan-Vickers Company is another promising design. The first Westinghouse 30,000-kw. cross-compound machine, built for the Interborough Rapid Transit Company in 1914, with its two independent rotors running at 1,500 and 750 r.p.m. respectively, was followed by a 40,000-kw. unit of somewhat similar design, at 1,800 and 1,200 revolutions for the Narragansett Light and Power Company, and a 60,000-kw. three-cylinder unit for the Colfax Station of the Duquesne Company. With the three parts all in normal operation, this set will develop 50,000 kw. with a steam consumption of 10·93 lb. per kw.-hour. With one of the low-pressure cylinders cut out, it will develop 36,000 kw. for 12·5 lbs. per kw.-hour, and with the two low-pressure cylinders alone running on high-pressure steam, 50,000 kw. can be produced for 13·5 lbs. per kw.-hour. The steam pressure is 265 lb., the superheat 175 deg. Fahr., and the vacuum 28½ in.

For some 50,000-kw. turbines now under construction, the Westinghouse Company are using two-cylinder cross-compound machines with multiple exhaust blading. Mr. Hodgkinson highly commends the design of the 50,000-kw. set, which Messrs. C. A. Parsons and Co. are building for Chicago. It is thought likely that turbines of 50,000 kw. and over, and all large machines for steam pressures higher than 400 lb. per square inch will be constructed in future on the compound principle, although the General Electric Company, of Schenectady, has built very successful machines to develop 50,000 kw. at 1,200 r.p.m. in a single cylinder. A modern Westinghouse turbine to develop 35,000 kw. at 1,800 r.p.m. had multiple exhaust blading. The blades were of warped surface and of tapering section, so that the maximum stresses due to centrifugal force did not exceed 20,000 lb. at an overspeed of 20 per cent. The drum stresses under similar conditions did not exceed 18,000 lb. The steam was first expanded in nozzles from its initial pressure down to a pressure of about 120 lb. absolute. It then acted on an impulse element, having two running rows of blades with a mean velocity of 463 ft. per second. The impulse blades were 2½ in., 2 in., and 1½ in. wide respectively for the three rows. The reaction blading was arranged on a conical surface, to avoid eddies. A gain of efficiency of 2½ per cent. was attributable to this feature. To

make the turbine adaptable to extreme conditions of regenerative feed heating, four outlets were provided; from which steam might be bled off at pressures of 3½ lb., 16 lb., 50 lb., and 120 lb. absolute.

The Crawford Avenue Station of the Commonwealth Edison Company, at Chicago, which will operate with steam at 550 lb. pressure and a temperature of 725 deg. Fahr., is of unusual interest. After the steam has been used in high-pressure turbines elements, it will be reheated to 700 deg. and returned to lower pressure turbine elements. The station will contain three turbines, each built by a different company, all of the cross-compound type. One 60,000-kw. machine by the General Electric Company, will have a separate high-pressure element at 1,800 r.p.m. expanding the steam down to 120 lb. absolute, after which the steam is reheated and returned to a single low-pressure machine at 1,200 revolutions, in which it is expanded down to the condenser pressure. Another machine is the 50,000 kw. set built by C. A. Parsons and Co. The high-pressure element which runs at 1,800 r.p.m. will expand the steam down to 115 lb. absolute, after which it is reheated and returned to two lower-pressure elements of the two-speed tandem type, running at 1,800 and 720 r.p.m. respectively. The third machine built by the Westinghouse Company has the high pressure and intermediate pressure elements arranged as a tandem compound. At full load the high-pressure element expands the steam to 132 lb. absolute, after which it is reheated and expanded in the intermediate element to 16½ lb. absolute. It then passes to the low-pressure element which drives a separate generator.

Mr. Hodgkinson's paper, which is of great length and copiously illustrated, goes on to deal with blade design and materials, balancing, labyrinth packings, bearings and thrust blocks, and terminates with a section on condensing plant. It is a paper which will long be referred to as a comprehensive and authoritative pronouncement on the design of large turbines and condensing plant.

The attendance for the discussion of these papers included many men famous in the power-station and turbine field from both sides of the Atlantic, and most of the leading designers in this country were also present. It is probable that so representative or authoritative a gathering of steam plant engineers has never before been assembled, and the excellent chairmanship of Mr. John Lieb did all that was possible to provoke a useful discussion. In calling upon the four authors to read abstracts of their papers, Mr. Lieb paid a sincere tribute to the work of Sir Charles Parsons in making the turbine a technical and commercial success. The development of the turbine had brought about an intensive study of thermodynamics, and the effect of the invention had also been felt down to the smallest detail of the auxiliary plant. The old steam engine was a wonderful machine, but the coming of the turbine had doomed it in large sizes. The speaker had personally known steam engines of 3,000, 4,000 and 5,000 horse-power, scrapped even before they had run long enough to work their bearings down properly and the price obtainable for the scrap metal was less than the cost of pulling out the engines. The increase of steam pressures and temperatures had brought about serious metallurgical problems. The fundamental requirements of large generating units was absolute reliability in service, and the reliance the public placed upon continuity of supply must not be shaken. It looked somewhat as if the designers of impulse and reaction machines were more and more approaching each other and finding common ground. In the United States new power stations were based on capacities of 300,000, 400,000 and 500,000 kilowatts of installed plant, with units of 30,000, 50,000 and 60,000 kilowatts rating. Machines even of 100,000 kilowatts were under consideration by designers at the present time. The placing of orders of three 50,000 kilowatt units at one time was not uncommon in the United States, and this fact showed what ideas were held with regard to superpower stations.

In giving a resumé of his paper, Sir Charles Parsons said that before 1884 there were 100 turbine patents, none of them taken out by himself. In those 100 patents would be found described nearly every principle necessary or in use to-day. Mr. Curtis had introduced an element of novelty, but Mr. Lieb had not mentioned the important work of this inventor possibly for reasons of national modesty. Mr. Curtis and Dr. De Laval had developed the expanding nozzle. De Laval had been the first to use reduction gear, and the idea of compounding turbines was due to a Scotch clergyman named Wilson. As Mr. Stork was not present the Chairman called upon Mr. J. Strumpf to present a resumé of the second paper. Mr. Strumpf stated that his firm were building what was known as the Erste-Brunner turbine. This was designed by Mr. Loesel who was formerly with Zoelly. He took the Curtis wheel and the dummies out of a turbine of the Parsons disc and drum type and replaced them by single impulse wheels, taking the thrust on thrust-collars. He then built a turbine, having impulse wheels in one cylinder and reaction blading in the other. The principle feature of the Erste-Brunner turbine was that it had a great many stages but not too many in one casing. The machine was designed to work below its critical speed. The third paper was read by Mr. Ekstrom in Mr. Nordströms absence and Mr. Hodgkinson read an abstract of his own paper.

The discussion was opened by Mr. Junkers of the General Electric Company who claimed that his company had always recognised the advantages of large units. The vertical turbines built from 1902 to 1914 had been constructed up to 20,000 kilowatts, and the company had built 783 such machines, aggregating 2,163,700 kilowatts. Up to the present date there had also been constructed 234 units of 10,000 kilowatts and greater capacity embodying a Curtis wheel followed by single impulse wheels. These aggregated 3,250,000 kilowatt capacity. Of machines using single impulse wheels throughout, the Company had constructed 133 of 15,000 kilowatt and greater capacity, aggregating 4,000,000 kilowatts. They had got 15 machines developing 30,000 kilowatts at 1,800 revolutions in service, and 19 in course of construction. They would build machines of 40,000 kilowatts at 1,500 revolutions per minute, and from 45,000 to 50,000 kilowatts at 1,200 revolutions per minute. The General Electric Company had 460,000 kilowatts of machines to work with steam from 530 lb. to 600 lb. pressure built or on order. These were designed for reheated steam. The speaker mentioned other large machines and said that units of 100,000 kilowatts would be considered in the near future as there was no limit to size except demand.

Dr. S. Z. de Ferranti, who followed, spoke of his experiences in turbine design and construction. In 1902-1903 he had come to the conclusion that the right thing to do was to build a re-superheating turbine so as to work as nearly as possible on the lines of isothermal expansion. The idea was for the steam to do its whole work at a high temperature, not in falling from a high to a low temperature. He decided to employ a moderate steam pressure, namely, 200 lb. per square inch and reheat the steam at as many points as possible. This involved the use of a regenerator next to the condenser to utilise the heat in the exhaust steam. In the year 1910 he had built a 3,000-kw. 3,000-rev. machine, with no dummies, but a thrust bearing to take the end pressure. Parsons reaction blading was employed and practical considerations limited the reheating points to two only. Later on a regenerator was placed in the exhaust. The turbine was bled at four places for feed-heating. It had a wrought steel casing, and inside this was other steel construction. The blades were fixed by electric welding. The machine supplied a great deal of power for Messrs. Vickers' works at Sheffield. The initial superheat was to 750 deg. F. The steam was exhausted while still containing superheat and re-heated in another superheater before passing to the second part of the machine. A special alloy was used for the superheated tubes, consisting of 25 per cent. nickel steel, but it was afterwards found that ordinary steel was just as good. There was some difficulty in drawing the 25 per cent. nickel steel tubes, but this was got over by coating them with copper before drawing, which greatly facilitated the operation. Wonderful results as regards economy had been obtained, and enough work had been done to put the machine on the market, but circumstances prevented this, and the speaker had abandoned the work. Four years ago he had returned to the idea of doing work at high temperatures, and had built a turbine with a 10-in. wheel running at 26,000 revs. This had run for many hundred hours at 900 deg. C., when the wheel was at a bright red heat.

Sir Charles Parsons stated that the failures experienced with reheated steam in the early days were due to the growth of cast iron, a phenomenon which was not at first recognised. Mr. J. P. Chittenden considered that Mr. Hodgkinson had been a little hard on impulse turbines as regards danger from disc vibration. There had been only two cases in this country where failure had been definitely traced to disc vibration. With regard to the type of turbine discussed in Mr. Stork's paper, the proposal to use many stages and a special construction of rotor could hardly be put forward as a new idea. An examination of the design of Parsons' marine turbines would show a very large number of stages in comparison to the value of K; in other words, the K in such designs was of good quality. On the other hand, considering impulse machines, it was generally known that in America a 40-stage impulse machine was built some years ago and gave satisfactory results on test. Furthermore, marine impulse turbines had not only a large number of stages, but the discs and shaft of the high-pressure turbines had been machined from a solid forging, as in the case of the Erste-Brunner machine. Mr. Chittenden did not wish to appear to criticise the design, but to point out that its salient features were and had been adopted where consideration of steam conditions, output, &c., indicated that the features would be advantageous.

Mr. Chittenden further endorsed the view that when extra high pressure was used, not only should the high-pressure end of the turbine be entirely distinct from the low-pressure end, but its speed of rotation should be considerably higher if leakage and windage losses were to be kept down and a good arc of admission obtained. At Rugby the English Electric Company had built a 1,000-kw. turbine to work with a pressure of 1,500 lb. per square inch, and a speed of 25,000 r.p.m. had been chosen for the high-pressure end. This, we may remark, is to work in conjunction with the Benson 3,200 lb. boiler which has been satisfactorily tested, and the whole combination appears to offer possibilities which should not be disregarded by those interested in advanced power station practice. Mr. Chittenden also advocated the "straddle" type of blading, as used by some makers as the strongest and lightest method of fixing impulse blades.

Mr. K. Baumann, speaking on the advantages of the multiple exhaust system, referred to recent tests of a 7,000-kw. 3,000-revolution machine at Bristol, carried out with the view of finding out the exact value of the system. The two stages embodying the multiple exhaust were removed, and careful tests made under conditions of constant load and vacuum. The parts were then replaced and the tests repeated with the same quantity of steam passing through. When working with a 28·6-in. vacuum the efficiency was lowered 6 per cent. by the removal of the multiple exhaust. The effect of the multiple exhaust was equivalent to increasing the vacuum from 27·8-in. to 28·6-in. In other words, the multiple exhaust dealt with a 60 per cent. larger volume of steam with the same overall efficiency. Referring to the Erste Brunner design, Mr. Baumann said there was nothing new in the use of a two-cylinder machine for high pressures, and it was also recognised that stages of relatively small diameter were advantageous in the high-pressure cylinders. Mr. B. Pochobradsky, speaking on the same subject, said that the recent researches of the Beama and the Institute of Mechanical Engineers, had proved that nozzle efficiency was a maximum at a steam speed of about 300 ft. per second, and after falling off beyond that speed, it rose to a second maximum at about 1,500 ft. per second. This indicated that a high-pressure turbine should have many stages of small diameter, and a low-pressure turbine should have a large diameter. The joint of a very high pressure casing was troublesome, and the speaker advocated a double casing for the high-pressure turbine, the parts being co-axial with a steam jacket at medium pressure between. This relieved the pressure on the joints. Mr. Konig, the next speaker, mentioned

the decrease in efficiency which took place with higher steam temperatures, and said that the most economical temperature was that at which the steam was just superheated at the exhaust. The expansion line of the steam should run parallel to the saturation line, and if the steam could be continuously reheated this might be possible, but the idea did not appear practicable. Like previous speakers, Mr. Konig saw no great novelty in the Erste Brunner design, as it appeared to contain no features which were not well known in turbine practice.

Mr. George Orrok said that we heard of efficient turbines with numbers of stages ranging from 8 to 80. The variation of design considered with regard to the uniformity of the generators was most astonishing. What the central station engineer wanted was a turbine which would be ready for service for 8,760 hours in a year, that could be started up in two minutes from cold and would not deteriorate with time or service. Mr. Watson hoped that some speaker would give the relative value of two 20,000 kw. turbines as compared with one of 40,000 kw. capacity. He was glad that the frequency standard of this country prevented direct-coupled units from exceeding a limit of 3,000 r.p.m. It would be interesting to know what sizes the Americans would build up to their limit of 3,600 r.p.m. Mr. Moulthrop, of Boston, said that his company served an area with practically no factory load, and the lowness of the load factor made capital charges a very important consideration in the design of their stations. They had built a simple, reliable and standard kind of station and superposed on that was a boiler and turbine to work at 1,200 lb. pressure. By this means they had got extra capacity as well as increased efficiency, and the increased capacity had resulted in the unit cost of the whole plant being no greater than that of a standard station. Mr. Bernard Price, of the Victoria Falls Power Company, speaking as one who was connected with the largest coal-burning power undertaking in the Empire, said that the cost of fuel had a great bearing upon the expense which was justifiably undertaken in obtaining efficiency. Furthermore the amount and skill of the labour required for operation and questions of maintenance were very important in countries far from the makers' factories.

The replies of the authors were brief. Mr. Cook, replying on behalf of Sir Charles Parsons, did not consider that Mr. Pochobradsky's double casing was yet necessary. With regard to the advantages of efficient turbines, it should be pointed out that, although the turbine itself might cost more, the boiler plant was smaller and cheaper, and coal and ash-handling equipment were all reduced. Mr. Frank Hodgkinson said that one of the most valuable features of double-cylinder machines was the possibility of running the two rotors at different speeds, thus permitting a small diameter for the H.P. rotor and a large diameter for the L.P. rotor. The difference in the standard frequency of alternating current in Great Britain and the States, with the corresponding limiting speeds of 3,000 and 3,600 r.p.m., had a distinct effect on design. With regard to the question as to what size of machines could be built for 3,600 r.p.m., he could say that generators up to 12,500 k.v.a. at 3,600 revolutions were now under construction.

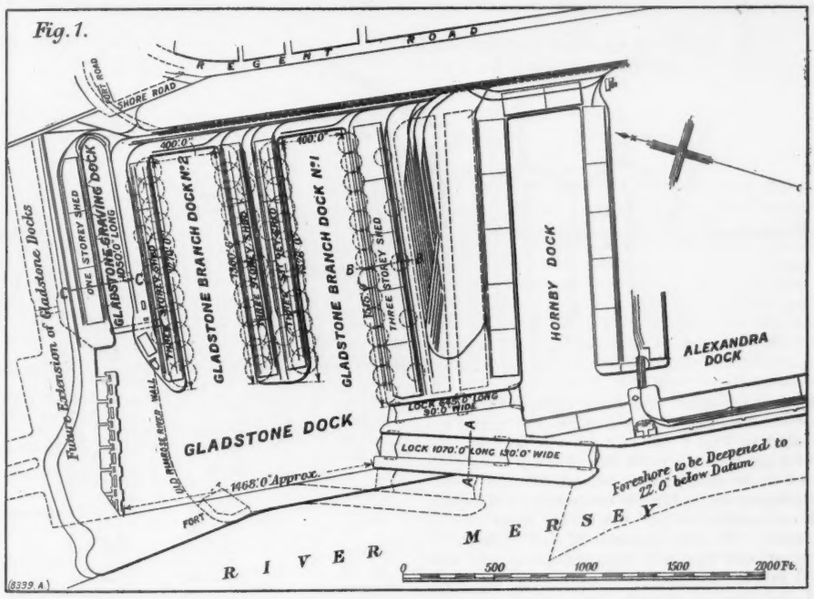
We will continue our report of the proceedings in our next issue.

THE NEW GLADSTONE DOCK SYSTEM AT LIVERPOOL.

THE works which are under construction at the north end of the Liverpool dock estate constitute one of the most important and extensive pieces of dock engineering now being carried out in any part of the world. The docks under construction will complete the Gladstone dock system which includes a new river entrance, the Gladstone dock itself, and the two Gladstone dock branches. The system also incorporates the Gladstone graving dock, which was completed and put into service in 1913. This Gladstone dock scheme was first planned some time before 1906, and Parliamentary approval for it was obtained in that year. At that time, however, the state of trade did not appear to justify the immediate embarking on a scheme of such magnitude and nothing was done for a few years. A start was actually made on the works in 1910, and was to some extent determined by the decision of the Cunard Company to proceed with the building of the Aquitania. To provide the dock accommodation required by that vessel, the graving dock part of the Gladstone scheme was put in hand, and in order that the facilities provided should be as extensive as possible the somewhat unusual course of providing one quay of the graving dock with transit sheds was adopted. This enabled the dock to be utilised either as a graving dock or as an ordinary wet dock. Incidentally, it may be said, that the decision to construct this graving dock in advance of the main works proved of very great value and importance on the outbreak of the Great War some twelve months after it was completed. The value of the addition to the graving dock facilities on the Mersey which it represented would be difficult to exaggerate.

A general plan of the Gladstone dock system is given in Fig. 1 annexed. This plan represents the extreme northernly end of the dock estate on the Liverpool side of the Mersey, but the foreshore

Fig. 1.



for a distance of more than a mile beyond the Gladstone dock embankment is the property of the Mersey Docks and Harbour Board, and further extensions in a northernly direction may be undertaken in the future. The possibility of such extensions has been kept in view in the design of the Gladstone dock and the new river entrance. The graving dock is built to the north of the Rimrose river wall, which formed the northernly boundary of the dock estate for many years. This wall, which is indicated by a broken line in Fig. 1, was completed in 1875. The area enclosed by this wall represents reclaimed land which was filled up to Hornby dock quay level throughout, the earth filling for the area coming from the excavation for the Langton, Alexandra and Hornby docks. Since, as we have said, the Gladstone graving dock was built and brought into use independently from the main Gladstone scheme a special entrance from the river had to be constructed for it. The arrangement was, however, of a temporary nature only, and when the main works are completed the main river wall will be carried across, as shown in Fig. 1, to meet the graving dock entrance embankment and access to the graving dock will be obtained through the new Gladstone dock river entrance.

We described the graving dock works very fully in our issue of July 4, 1913, and as our present purpose is to deal with the progress of the main wet dock works it is not necessary that we should now describe the graving dock or its construction in any detail. In order to give a proper idea of the extent of the whole scheme, however, it will be well briefly to indicate its main features. This Gladstone graving dock is the largest graving dock in Europe, having a length from the head to the inner caisson sill of 1,050 ft. The width at the entrance is 120 ft. and the width of the dock is 141 ft. at the bottom and 155½ ft. at the top. At high water spring tides the depth of water on the sill is 45 ft. To enable full advantage to be taken of the depth of water over the sill by boats of deep draught an entrance channel was dredged in the river bed to a depth of 27 ft. below the Old Dock sill datum. The dock was built by first tipping a dam around the site of the works. This was made with a clay core, and was formed with a rubble face on the outward sides. When the site was completely enclosed the graving dock walls were built in timbered trenches. Timberwork dolphins were built on the entrance side of the tipped dam, while similar dolphins were constructed on the outer north face of the Rimrose river wall. This formed a wide splayed entrance, which was dredged to a depth of 27 ft. below Old Dock sill. The outermost portion of the tipped dam, with its timberwork, will form the northern boundary of the Gladstone dock, as shown in Fig. 1. The timberwork on the outer face of the Rimrose river wall has, however, been removed, and is not indicated in Fig. 1. As will be clear from the figure, this wall itself will be removed, and entrance to the graving dock will be obtained from the Gladstone dock. As indicated in Fig. 1, the main north and south river wall is being extended to the outer end of the tipped dam so as completely to enclose the Gladstone dock area. The extension of this wall has, of course, closed the river entrance to the graving dock, and the dock is at the present time out of commission. The final arrangements when the works are completed will offer great advantages over the direct river entrance to the graving dock, the use of which had naturally to be timed to suit the tides. Entrance from the Gladstone Dock will be possible at any time.

Turning now to the new Gladstone wet dock system, with which we are here more particularly concerned, it will be seen from Fig. 1 that the completed scheme will consist of the Gladstone Dock proper which has an area of 22 acres. This will in the main serve as a vestibule or turning dock giving ready access for the largest vessels to either of the branches or to the graving dock. Of the two Gladstone Branch Docks, No. 1 is 1,420 ft. long and 400 ft. wide, and No. 2 is 1,285 ft. long and 400 ft. wide. Access to the Gladstone dock system is obtained through the new river entrance lock, which, as will be seen, lies in an almost direct north and south line so that large steamers of high freeboard entering the dock in a north-westerly gale, which is the worst local condition, will move approximately against the wind so that they can

be kept well under control. The lock is 1,070 ft. long and 130 ft. wide and is divided into two sections so that the smaller boats can be locked in with a smaller loss of water. The sills are 30 ft. below Old Dock sill or 20 ft. below Bay Datum. The arrangement provides 21 ft. 4 in. on the sills at low water on ordinary spring tides and 28 ft. 7 in. on neap tides. At half-tide level there is 35 ft. of water over the sills, and at high water ordinary neap tides 41 ft. 7 in. and high water ordinary spring tide 48 ft. 10 in. These conditions will allow the largest ship in existence to enter or leave the dock on every single tide in the year while more ordinary boats of, say, 28 ft. draught, will be able to go in and out of the dock at any time of the day except for a very small number of hours each side of low water on spring tides.

The total water area of the system is 55¼ acres and there is a quayage of 2¾ miles. The branch dock quays are furnished with treble storey sheds and fully equipped with electric cranes, while very extensive railway connections and sidings are provided as shown in Fig. 1. The ground covered by the sheds amounts to 13¾ acres and the total gross floor area available for storage in the sheds is 55 acres. This area includes that of the flat roofs which are designed to take light loads. The arrangements of some of the sheds and cranes are indicated in Fig. 2 and 3. As will be seen, the existing sheds on the north side of the graving dock are of single storey type, 30 cwt. electric cranes travelling on one rail at the outer edge of the quay, and on another on the top of the front wall of the shed. The arrangements of the three-storey sheds at the new wet dock branches are indicated in Fig. 3, which is a section of the south wall and shed of Branch Dock No. 1. A 40-ft. passage way is provided between the front of the shed and the quay edge on this south wall, and two lines of railway track are carried along the quay, one of which runs between the legs of the 30-cwt. to 3-ton travelling electric cranes. These cranes can deliver material to a ship from wagons on either of the railway tracks or from the quay to any floor or the roof of the shed or *vice versa*. The sheds are fitted with large electric lifts which enable material to be easily transported between the ground floor and any of the other floors. Material may also be worked by the cranes direct from any floor through portals provided for the purpose. The south side of this shed is provided with 20-cwt. roof cranes which have a reach over two railway tracks and can deliver material to a wagon standing in the roadway beyond two lines of railway trucks. The sheds between the two branch docks are provided with 30-cwt. to 3-ton roof cranes on the water side and 20-cwt. roof cranes on the road sides. Only one line of railway track is in these cases laid in front of the sheds, but a second line is carried inside them. The sheds are constructed in ferro-concrete throughout, and two views of them during erection are given in Figs. 9 and 11 on Plate VIII.

As will be seen from Fig. 1, in addition to the new river entrance to Gladstone Dock there has been provided an entrance from the Hornby Dock by means of a lock 645 ft. long and 90 ft. wide. Although dwarfed to some extent by the remarkable river entrance this lock, it will be realised, is a very large one and will as a matter of fact allow by far the greater proportion of modern shipping to pass through. This lock incidentally adds to the value of the docks immediately to the south of the Gladstone system, since it will allow boats of deep draught to pass out from these northern docks to the river by means of the Gladstone entrance at times when the depth of water in the river would not allow them to pass out by their normal Canada and Sandon river entrances. This Hornby lock was the first part of the new Gladstone wet dock system to be completed and has proved of great value in connection with the main excavation work as it has been used as a depot basin for hopper barges removing the spoil. Simultaneously with the construction of the Hornby lock, work was started on the river entrance and the quay walls for the branch docks, Branch No. 1 being first dealt with. The construction of the branch dock quay walls was in a sense a simple and straightforward job but was one of very great magnitude. The quays are 63 ft. above dock bottom. The work was carried out in timbered trenches in the usual way and a satisfactory rock and gravel foundation was found at a level some 6 ft. below dock bottom. The walls are in mass concrete, a tunnel being formed below the quay and above high water level for carrying water-service pipes, cables, &c. Some idea of the height of these walls and the magnitude of the work generally will be obtained from the three views of the No. 1 Branch given in Figs. 5 to 7 on Plate VIII. These walls are now completed and the dump from Branch No. 1 has been removed, while the excavation of Branch No. 2 is well forward. The excavation has been carried out by five Ruston steam diggers, three of 2 cubic yards capacity, one of 1½ cubic yards and one caterpillar digger of ½ cubic yard capacity. The spoil was removed by trains of tipping trucks hauled by steam locomotives. Some of it was utilised for tipping an earth bank for forming the new river entrance and wall, the remainder being removed by hopper barges and tipped at sea. Temporary lines were laid in the dock bottom for working the trains and were, of course, shifted about and modifications made in their arrangement to suit the progress of the work. Connection was made to the quay railways to allow the wagons to be brought up alongside the Hornby lock for tipping into the hopper barges.

As the quay walls are now complete and Branch No. 1 completely excavated it would be possible to admit water to the system at any time and utilize this branch. This procedure would, however, naturally admit water to Branch No. 2, so that the remainder of its excavation would have to be done by dredgers. This procedure could not be carried out until after the completion of the river entrance, but that part of the work is well forward and will be finished very shortly. Branch No. 1 could, of course, not effectively be utilized until the sheds and quay equipment were ready, but this part of the work also is in a forward state. We understand that the decision to complete the work in the dry or to admit water to the system will depend on the demands that may arise on the accommodation of the port. The sheds on the south quay of Branch No. 1 are in a particularly advanced state, while those on the north quay are well forward. As these sheds are very heavy structures and stand on made ground, piling has been put in below the main foundations, as shown in Fig. 3. The piles are of ferro-concrete of 40 or 50 ft. lengths and were made on the job. The amount of concrete to be poured in the construction of the sheds is very large and a battery of Ransome's concreting towers has been utilized. Some of them can be seen in Fig. 11, on Plate VIII.

The new river entrance and sea wall form the most difficult and interesting part of these Gladstone dock works. As will be seen from Fig. 1 the new lock cuts across the line of the old river wall, part of the west wall of the lock being outside this line. A section of this outer wall is shown in the section of the new lock given in Fig. 4. This outer wall was built inside sheet steel piling reinforced by a timber work and pile structure connecting it to the old sea wall. A view of the sheet piling dam looking from the river is given in Fig. 8, Plate VIII; an inside view during the construction of the dam is given in Fig. 10. The outer face of this sheet pile dam is, of course, exposed to the full current of the river and to what is at times a very rough sea, but it has been very successful, and no difficulty has been experienced in keeping it adequately tight. The piling was sealed with fine ashes dropped into the water against its outer face and carried into any leaks by the inflowing water. The piling was supplied by the British Steel Piling Company, Limited. As we have said, the lock is 1,070 ft. long and 130 ft. wide, the sills being 30 ft. below Old Dock Sill or 20 ft. below Bay Datum. A pair of centre gates are fitted so that the lock may be divided into two parts to conserve water when the smaller type of ship is being locked in or out. The gates, which are the largest hinged gates in the world, are of steel and are being constructed by Messrs. Sir W. G. Armstrong, Whitworth and Company. The inner pair of gates during erection is shown in Fig. 12, Plate VIII. As will be seen from Fig. 1, the foreshore outside the entrance is to be dredged to a depth of 22 ft. below Bay datum.

As already stated the connection from the new dock works to the northern arm of the graving dock entrance is now being made by tipping an earth dam formed from the spoil taken from the branch dock excavation. Timber piling faced with sheet steel piling is being driven on this bank and the new river wall built in a trench formed inside. Two views of this sheet piling dam work are given in

Fig. 2. GLADSTONE GRAVING DOCK. SECTION ON LINE C.C.

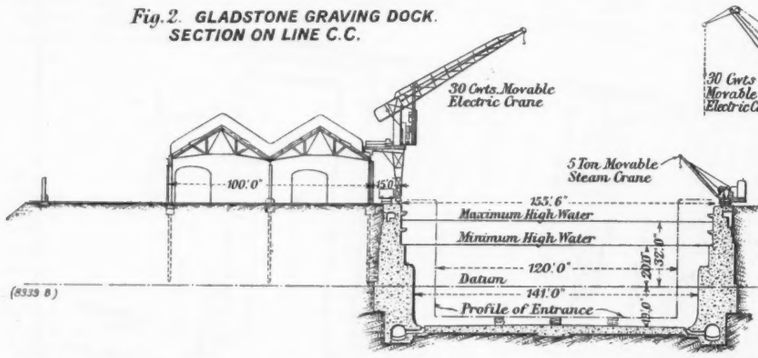


Fig. 3. SOUTH WALL & SHED. GLADSTONE BRANCH DOCK No. 1. SECTION ON LINE B.B.

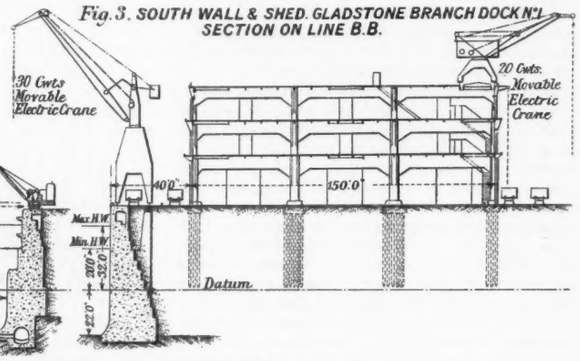
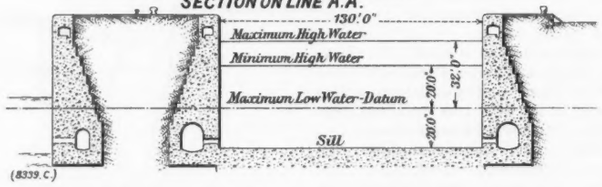


Fig. 4. RIVER ENTRANCE LOCK. SECTION ON LINE A.A.



ELECTRICAL GEAR FOR THE COLLIERY AT THE BRITISH EMPIRE EXHIBITION.

CONSTRUCTED BY THE METROPOLITAN-VICKERS ELECTRICAL COMPANY, LIMITED, ENGINEERS, MANCHESTER.

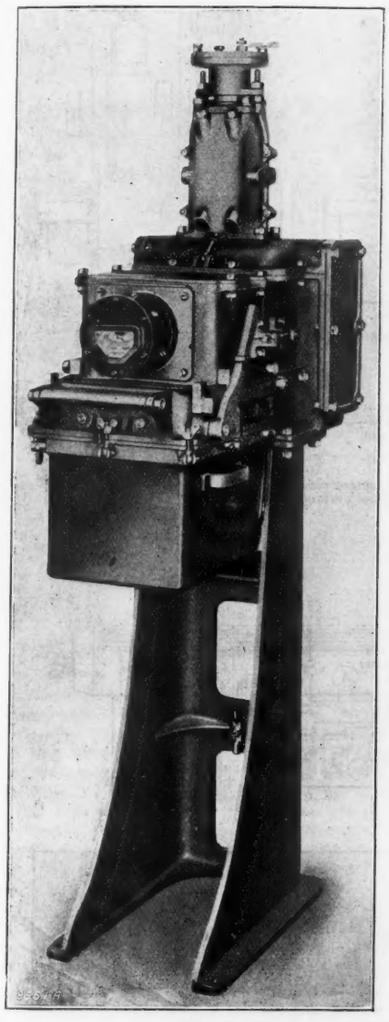


FIG. 67. 3,300 VOLT SWITCH PILLAR.

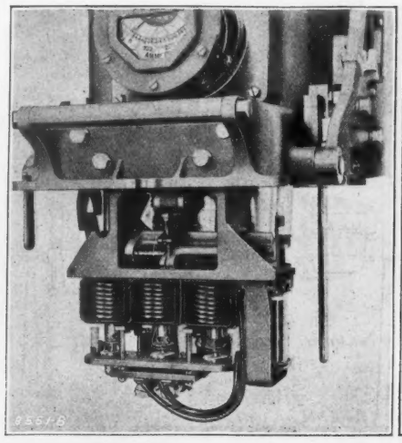


FIG. 68. DETAIL OF OIL SWITCH, FRONT VIEW.

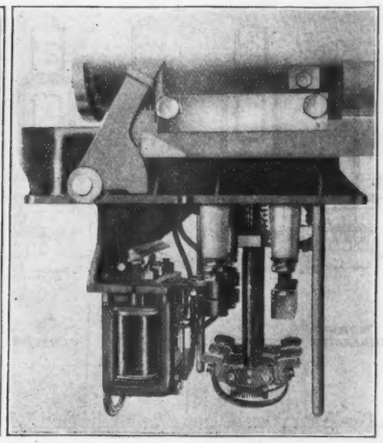


FIG. 69. DETAIL OF OIL SWITCH, SIDE VIEW.

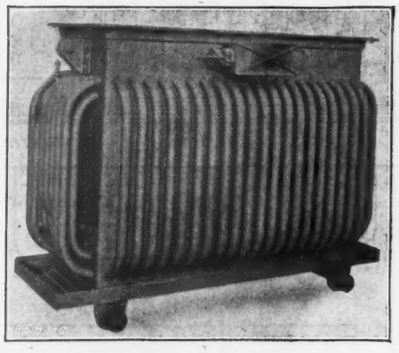


FIG. 70. 300 KV.-A. COLLIERY TRANSFORMER.

Figs. 13 and 14 on page 54. As will be clear, this work is being carried on practically in the open sea, and forms a remarkable testimony to the possibility of sheet steel piling. As will be seen from Fig. 1, the works are so planned that if necessary a second river entrance lock may be built alongside the first. This will probably be required if, and when, still further dock extensions take place to the north, when arrangements would probably be made for access to be obtained to them from the Gladstone entrance. In view of the possible construction of this second entrance the quay on the inside of the river wall, which it would intercept, has not been built up in concrete, but a piled timber quay has been constructed which could be removed with little difficulty. The whole of the work in connection with this extensive and important scheme is being carried out by direct labour under Mr. Thomas M. Newell, M.Inst.C.E., the Engineer-in-Chief to the Mersey Docks and Harbour Board. Mr. J. A. Newell, A.M.Inst.C.E. is acting as Resident Engineer on the new entrance and river wall works, and Mr. G. E. Cheslyn Callow, A.M.Inst.C.E. as Resident Engineer on the new branch docks.

THE COLLIERY AT THE BRITISH EMPIRE EXHIBITION.

(*Continued from page 795 of last volume.*)

HIGH-TENSION SWITCH-GEAR.

THE switch-gear handling the 3,300-volt, three-phase supply consists of a three-pillar board made by the Metropolitan-Vickers Electrical Company, Limited, of Manchester. It is built up of flame-proof, mining-type switch pillars (Fig. 67), a form which has been found satisfactory after a severe flame-proof test carried out by the mining department of the University of Sheffield. All the pillars are 150 ampere units, and are so arranged that the incoming supply of 3,300 volts is fed through one pillar on to the bus-bars and from the bus-bars out by the other two pillars to the 300-kv.-a. and 50-kv.-a. transformers respectively. The instruments on these pillars are also of Metropolitan-Vickers manufacture. This pattern of mining switch-gear is the result of many years' work in the development of iron-clad switch-gear. It is constructed with wide machine-faced joints throughout, so as to be suitable for use in mines and other places where the atmosphere is liable to contain inflammable material. All the live parts are completely enclosed in such a manner as to be flame-proof. The electrical design provides large areas for contact, low-current density, porcelain insulation, and ample clearance between the live parts and the case. The working parts are designed of sufficient strength to withstand many years' severe service, and the wearing parts are readily accessible for inspection and renewal. The circuit-breaker is of the loose-handle type with two breaks per phase under oil. There is quick-break action and the arcing contact pieces are renewable. Overload and no-volt automatic features are provided, all the coils being oil-immersed to ensure protection to the insulation and cool-running conditions. The coils and trip gear are shown in Figs. 68 and 69. Barriers are fitted in the tanks between phases and also between the protective devices and the switch contacts; explosive gases are prevented from passing from the oil chamber to other compartments of the gear. The circuit-breaker can be tripped by the operating handle, and also by a special trip lever (see Fig. 68) mounted on the opposite side of the breaker, which can be held temporarily against the spring to render the overload trip inoperative when starting a motor. The entire circuit-breaker can be withdrawn clear of all live metal, so as to eliminate all risk in making inspection, adjustment, cleaning or repairs, and it may be removed completely and replaced by another circuit-breaker.

Special features are included to give automatic protection and to guard against the mistakes that are liable to be made by careless or unskilled operators, as follows: it is not possible to withdraw the switch carriage before tripping the switch; no current can be interrupted on the plugs; an auxiliary switch opens the potential circuits. The circuit-breaker and carriage may be permanently locked in either the open or the closed position to prevent unauthorised operation; the oil tank cannot be lowered until the breaker is tripped and the carriage withdrawn, nor can the switch carriage be plugged in with the oil tank removed. The breaker cannot be closed unless the carriage is properly plugged in.

The overload coils are arranged for direct connection and may be set to operate at any value between normal full load and an overload three times as great.

TRANSFORMER-ROOM SUPPLY.

In the transformer room are two Metropolitan-Vickers transformers of the colliery type, one of 300 kv.-a. (Fig. 70) and the other of 50 kv.-a. These transformers take current from the 3,300-volt, 50-cycle supply, and are of the core type supplied with tappings on the high-tension winding, giving a variation in voltage of plus and minus 2½ per cent. and 5 per cent. The large transformer is fitted with high-tension and low-tension trifurcating boxes, rollers, under-carriage, and thermometer, and it supplies power to the various coal-handling and cleansing devices exhibited in the colliery.

SWITCHGEAR FOR THE COLLIERY AT THE BRITISH EMPIRE EXHIBITION.

CONSTRUCTED BY MESSRS. GEORGE ELLISON, ENGINEERS, BIRMINGHAM.

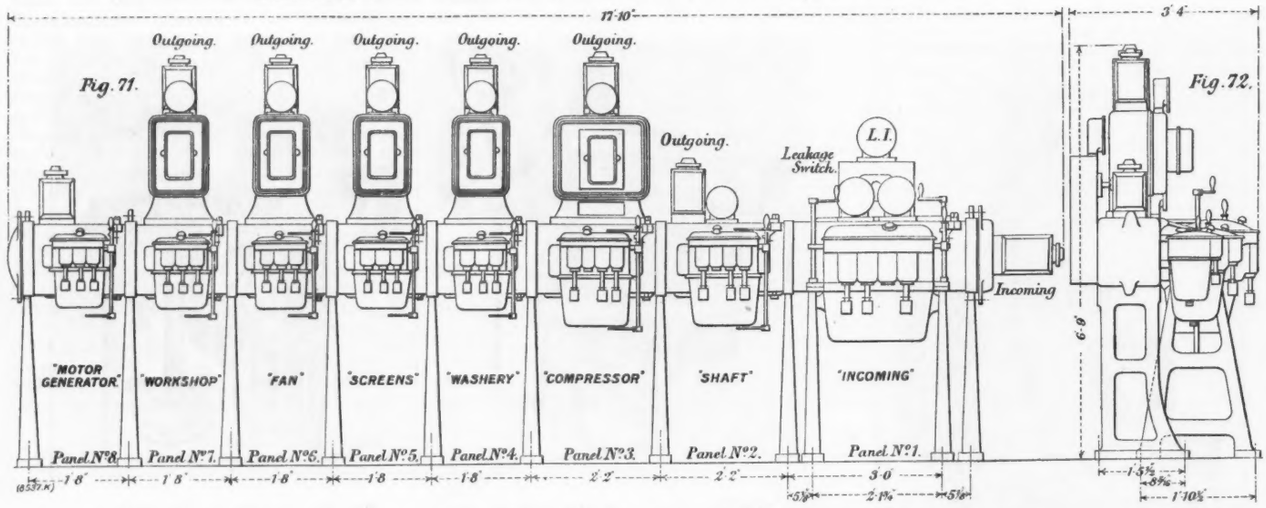


Fig. 71.

Fig. 72.

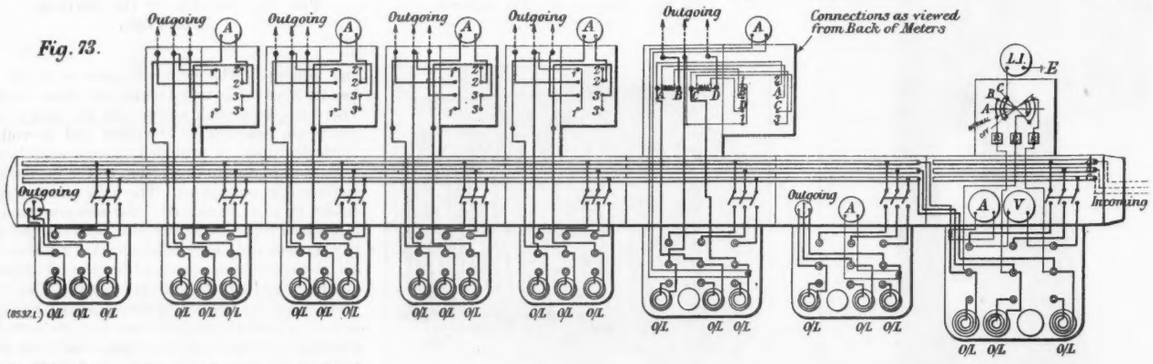


Fig. 73.

The 50 kilovolt-ampere transformer is supplied from the same source, and is fitted with tappings on the high-tention windings giving a variation in voltage of plus and minus 5 per cent. It supplies current for lighting the colliery and is similar in detail to the larger transformer.

Low-tension Switch-gear.

The 440-volt, three-phase current from the transformers passes to an eight-unit service switchboard, by Messrs. George Ellison, of Birmingham. This is shown diagrammatically in front view in Fig. 71, in side elevation in Fig. 72, in plan in Fig. 73, and in a general view in Fig. 74. It controls an incoming feeder and outgoing feeders to the shaft, air compressor, washery, screening plant, fan, workshop and motor generator. Each unit of the switchboard comprises an automatic circuit-breaker bolted on to a rectangular bus-bar chamber, supported independently on cast-iron stands. The bus-bar chamber is built of steel plates in the form of a box girder, the units being bolted together and the copper bus-bars joined up with links, to make a continuous structure. This construction is strong mechanically and is used for switch-gear in every industry where totally enclosed protective and protected switch-gear is required. The bus-bars are clamped to steel rods covered by synthetic resin insulation, and the supports may bend to allow for distortion which occurs in a mine where the floor is continually altering in level. Cases have occurred where a fall of roof has broken the stands and driven them into the floor without causing any interruption of the supply or necessitating a more expensive repair than the renewal of the stands and the flattening of the twisted plates of the bus-bar chamber.

All the circuit-breakers have three automatic overload trips fitted with time-lag devices, and isolating links are provided to disconnect them from the bus-bars for inspection. A complete interlock ensures that the breaker must be "off" before the isolating links are operated; the breaker cannot be closed unless the isolating links are fully opened or closed; the breaker tank and cover cannot be removed unless the isolating links and the breaker contacts are both open. The locking gear is secured in the "on" or "off" positions by a padlock.

The incoming feeder unit carries an ammeter, voltmeter, and leakage indicator. Other units carry ammeters and watt-hourmeters. A good mechanical job is made of the armoured cable connections by securing them to sectional end

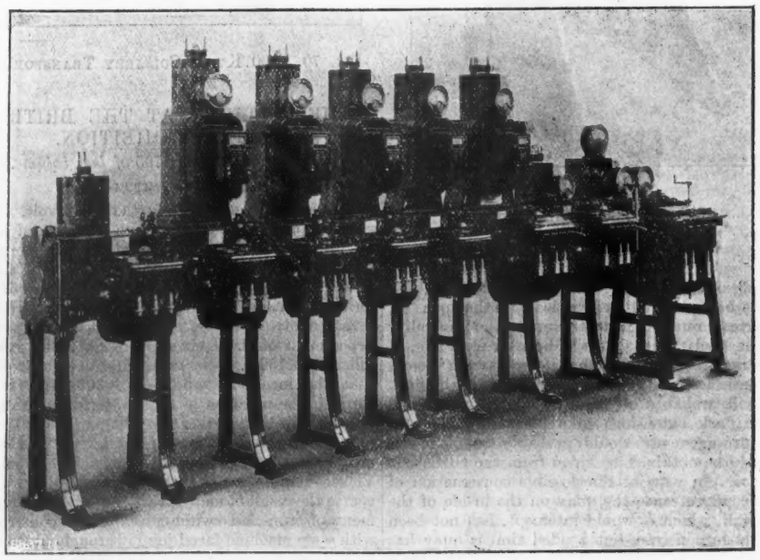


Fig. 74. General View of Switch Pillars.

ELECTRICAL GEAR FOR THE COLLIERY AT THE BRITISH EMPIRE EXHIBITION.

CONSTRUCTED BY MR. GEORGE ELLISON, ENGINEER, BIRMINGHAM.

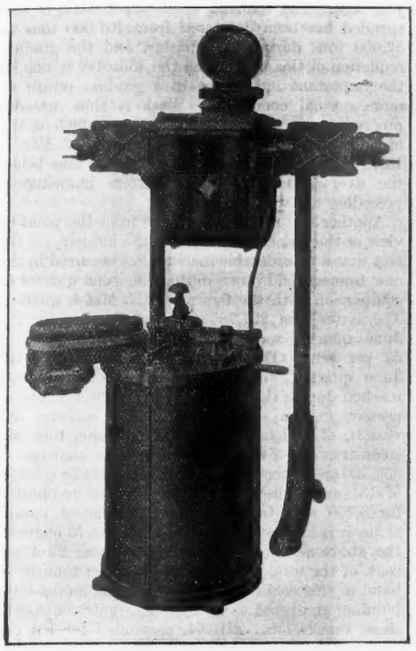


FIG. 75. CIRCUIT-BREAKER AND STARTER.

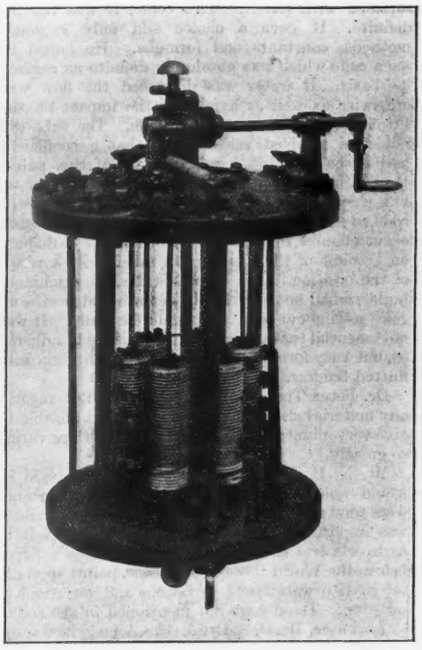


FIG. 76. STARTER REMOVED FROM TANK.

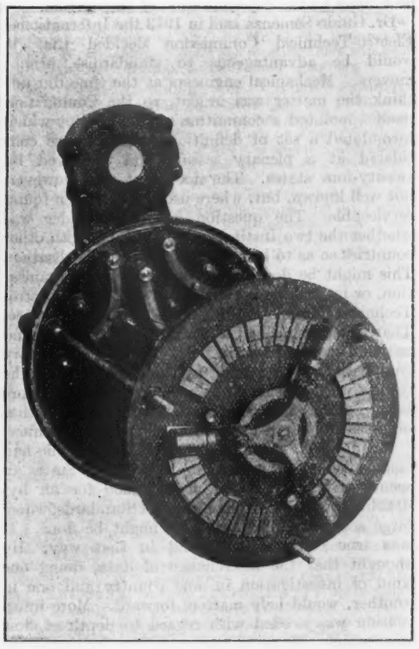


FIG. 77. STARTER SHOWING CONTACTS.

boxes fitted with cone clamps for the armour. These boxes have detachable side plates to enable the jointer to complete his work and connect up the tails unimpeded by the box which he finally assembles round the finished joint before running in the compound filling.

The underground power switchboard comprises an incoming feeder unit and four outgoing units, constructed similarly to the surface switchboard. There are also distribution boards for the screening plant and washery, of the same design but comprising four and three units respectively. The lighting switchboard, arranged on the east side of the transformer room, comprises six double-pole oil circuit-breakers carried on two bus-bar units.

A number of Ellison starting panels, of the type illustrated in Figs. 75, 76 and 77, are in use for the motors driving the auxiliary machinery at the mine, for example, for the starting and control of the 20-h.p. Brook motors driving the Marcus screens.

Another type of circuit-breaker of the air-break pattern, known as the "mill" type, is shown in Fig. 78. This illustration is of the type in ordinary use on the surface. The same pattern of circuit-breaker mounted in a heavy cast-iron box, with wide machined flanges, arranged as a gate-end box for use in a mine, is exhibited by the firm in the Palace of Engineering.

(To be continued.)

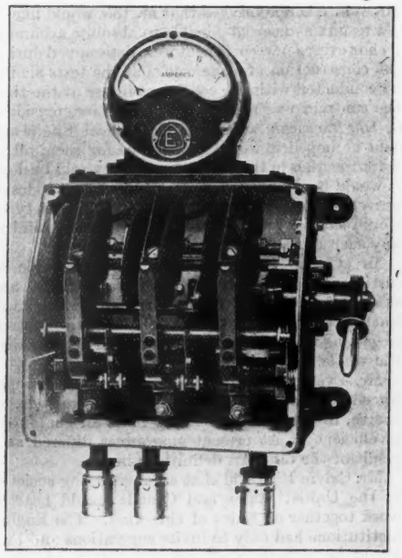


FIG. 78. AIR BREAK CIRCUIT-BREAKER.

TEST CODE FOR HYDRAULIC POWER PLANTS.

A JOINT meeting was held of the Institutions of Civil Engineers and Mechanical Engineers at Storey's-gate on Saturday, the 5th inst., to consider the draft "Standard Test Code for Hydraulic Power Plants" drawn up by the Joint Committee appointed by these two institutions. It will be remembered that this code was discussed at a meeting held on March 28 (see ENGINEERING, vol. cxvi, p. 439). The second meeting was called as it was thought that it would be well to take advantage of the presence of visitors at the World Power Conference, to secure if possible a wider range of criticism than the previous meeting had provoked. In a sense, the meeting was justified, since a large number of overseas and foreign engineers attended, a good number contributing to the discussion.

A few words by Mr. W. H. Patchell, who was in the chair, introduced the subject and served to welcome the many visitors. Mr. Patchell laid stress on the desirability, if possible, of arriving at a single test code to suit everybody.

Professor A. H. Gibson, the secretary of the joint committee, being unavoidably absent, Professor S. M. Dixon explained how the idea of the standard test code had originated. It was necessary in order that our engineers and manufacturers might compete with others, but an ideal code was difficult to attain. There were others in existence but it was not desirable to adopt these if an improved code could be designed.

Mr. Evan Parry, who was a member of the joint committee, spoke next as a member of the committee of the International Executive of the World Power Conference and of the sub-committee appointed by the conference to consider what action should be taken to secure an international test code. That sub-committee had met the previous day and there was a very strong desire to secure a common code. It was thought that this might be obtainable through the International Electro-Technical Commission and it was pointed out that an international code already existed in Publication No. 29 of this Commission, dated 1914. There seemed to be no object in duplicating organisation. The best course would be to refer the matter to that Commission so that the code might be brought into line with modern developments and other national test codes. There were already several codes; the American Society of Mechanical Engineers had one; there was the one then before the meeting; while paper No. 399 of the World Power Conference, by Professor G. Sundby, of Norway, was also a proposal for "Uniform Rules for Testing Water Power Plants." The points of difference were really slight and it should be possible to harmonise all these. The differences were matters of expediency rather than fundamentals.

Mr. Shepherd, of the Niagara Falls Power Company, speaking next, said the code proposed appeared to be very similar to the A.S.M.E. code, with the drawing up of which he had had to do. The draft code improved on theirs a little in some points. There were no essential differences between the two; it was merely a question of finding the best form of language in which to present the points. He certainly agreed with taking into account both static and velocity heads. With regard to draft tubes, there was a difficulty in separating the losses in draft tubes from those of the runner. When they considered the whirl in the draft tube more light was wanted in that connection. At present they had not got any satisfactory method of determining what the energy content of the whirl was. Then there was the question as to where the draft tube ended and the tail race began. Neither

code dealt with that point in satisfactory language. They were concerned with actual physical conditions and not with results derived by some particular method. The code should insist on actual quantities and any methods adopted for deriving these should be subject to the determination of their errors.

Dr. Guido Semenza said in 1913 the International Electro-Technical Commission decided that it would be advantageous to standardise prime-movers. Mechanical engineers at the time did not think the matter was urgent, so the Commission itself appointed a committee on the subject which formulated a set of definitions. These were considered at a plenary session and approved by twenty-four states. The document was, however, not well known, but, where used, it had been found serviceable. The question now to consider was whether the two Institutions should join with other countries so as to bring about wide standardisation. This might be done by setting up a new organisation, or by making use of the International Electro-Technical Commission if it could serve the purpose. That Commission had a chief office in London and national committees in each country. Advisory commissions were formed by the delegates, and the results were considered at plenary meetings before being adopted. He thought and hoped that organisation might be useful in the present instance.

Mr. John R. Freeman said for some time he had been working very hard in the United States to secure an appropriation of $200,000 for an hydraulic laboratory for the Bureau of Standards, where large scale experimental work might be done. It was true economy to spend in that way. He thought that the interchange of data, doing one kind of investigation in one country and one in another, would help matters forward. More information was needed with regard to depth of flow over weirs. Many of the conditions originally insisted upon by Francis were often ignored, but good results could be obtained if these were observed. Approaches should be free from all eddies. It was possible that large scale laboratory work might suggest a better type of weir than the sharp crested form. The outline of the code was well worked out; his suggestions were in matters of detail. The velocity of whirl could be measured. A long while ago he had been connected with work in which this was done. Two tubes were inserted at right angles diametrically across the draft tube. Each tube contained smaller tubes, each of which was connected with one of a series of small apertures in the main cross tube, and also with a gauge. A set of readings was thus obtained showing evidence of well-defined whirl. Some curious results were recorded and traced to vibration of the tubes. Whirl was important, as the angle of divergence of the draft-tube could be made greater because of it. In another connection they had found that eddies, of which no evidence whatever existed on the surface, were present at the bottom of a deep flume. These had to be eliminated by screens before reliable figures could be obtained. In whirl, he thought, lay the secret of the high efficiency which could be given to the draft tube. The code mentioned stilling boxes. These were very liable to introduce error and careful checks should be made of the height given in the stilling box and the actual depth on the weir. He had known the former to be taken with great accuracy when the latter was greatly in error. The size of Pitot tube openings was not so important as their correct placing. A 6-inch opening in a 10-ft. pipe would give perfectly satisfactory results if correctly set in the pipe. Orifices and diaphragms could be designed to give very different effects.

Mr. J. B. Challies said that, in view of the power developed and in course of development in Canada, the subject of a standard test code was of immense importance to that country. They usually employed the A.S.M.E. code, with adaptations. If the Institutions desired the opinion of Canadian engineers on the subject of the code, the Engineering Institute of Canada would be only to glad to obtain it.

Professor van Itersen said that the water temperature should be recorded in connection with weir measurements. Results obtained with the same methods in Europe and the Dutch East Indies showed differences of 2 per cent. Attention should be paid to the fact that comparisons should only be made in the case of equal Reynolds' figures.

Mr. W. M. White was not clear what the word "code" covered, nor what the code was to be used for. Was it to be used for scientific actual efficiencies, or as a measuring stick for agreement between buyer and seller? He, as a manufacturer, was not satisfied with the A.S.M.E. code; it was too indefinite. It gave a choice and only *suggested* methods, constants and formulæ. He hoped to see a code which was absolutely definite as regards its basis. If water was disturbed the flow was crosswise as well as axial and the impact on the Pitot tube orifice was at an angle. The tube did not read resolved velocities so that a coefficient had to be introduced to take care of this point. He did not care just what these coefficients were, but they should be set out in a paragraph in the code so that they could file guarantees on the basis of such figures, instead of them being open to dispute on account of the base figures taken. As a result of the position in the United States, the machinery builders had got together in defence and drawn up rules setting out how tests should be made. It was not essential that these should invariably be adhered to, but they formed the basis on which makers submitted tenders.

Dr. Peter Thoma, of Munich, could not suggest any material changes, but thought it inadvisable to give very minute directions as local conditions varied so greatly.

Mr. N. B. Jessen, representing Norway, said he would welcome an international code as turbines were now such large units and the export business was important. The draft referred throughout to hydro-electric efficiency. In Dr. Sundby's paper before the World Power Conference, points specially referred to were speed variations and variations in pressure. These were not mentioned in the code.

As a user, Mr. G. A. Orrok (U.S.A.) said he wanted to know that he was utilising the water in the best possible way; but if the definitions could be made to meet at once both the scientific and commercial points of view he would certainly agree to them. Mr. White here remarked that he, too, would like to get results as near as possible to absolute accuracy. If, however, a new coefficient were determined during the construction of some contract, the tests should be conducted with the coefficient in use at the time the contract was made. Mr. F. R. Low, president of the American Society of Mechanical Engineers, said he hoped it would be possible for them all to work together in this matter. If that could be done it would be possible to work out a series of codes of universal application. Speaking for his Society he would say they wanted to be active and useful in any such movement.

Mr. C. Le Maistre said it was desirable to distinguish between rules and regulations, and standardisation. There existed now in the Standardisation Committees in the different countries a means of getting into communication on such matters with the whole world.

Mr. Evan Parry said the discussion had brought up some interesting points. The desire was, of course, to obtain a satisfactory basis for guarantees of efficiency. At present guarantees differed as a result of the different definitions in use.

Mr. Calvin Rice said that all engineering societies in the United States and Canada would heartily work together on codes of this kind. The English institutions had only to invite suggestions and they would be definitely offered. A letter addressed officially to these bodies would certainly get a response. This he wished to contrast with the common attitude of waiting for help offered voluntarily. In the latter case assistance was seldom forthcoming, whereas a definite request would receive every attention.

The Chairman put it to the meeting that the recommendation implied in Mr. Rice's remarks should go forward as a resolution to the Joint Committee of the two institutions, and, this being carried, the meeting adjourned.

THE SHIPBUILDING INDUSTRY.

THE slightly improved activity in the shipbuilding industry for the first quarter of the year, which was recorded on page 470 of our previous volume, has been continued during the June quarter. According to statistics just issued by Lloyd's Register, the tonnage under construction in Great Britain and Ireland on the 30th ultimo was 1,516,746, which is 43,117 tons more than the corresponding figure for March 30, and 178,987 tons higher than that for a year ago. The tonnage upon which work is suspended has been decreased from 101,000 tons to 52,000 tons during the quarter, and the gradual reduction of this incubus on the industry is one of the important indications of a gradual return to more normal conditions. Work is thus actually proceeding on about 1,465,000 tons, which is the highest figure recorded since the end of March, 1922, although it is still about 425,000 tons below the average for the four quarters immediately preceding the war.

Another feature of importance from the point of view of the immediate future of the industry, is the fact that a considerable increase has occurred in the new tonnage laid down during the June quarter in comparison with the figure for the March quarter. The latter was 227,786 tons, while that for the June quarter was 375,210 tons—an increase of 65 per cent. The tonnage launched during the June quarter, viz., 364,518 tons, is the highest reached during the last 2½ years. The tonnage at present in the shipbuilders' hands includes 391 vessels, of which 324, making 1,157,406 tons are steamers, and 54 with an aggregate tonnage of 355,590 are motor-ships, while the remainder consists of 13 small sailing vessels and barges accounting for 3,750 tons together. The tonnage of motor-ships, it is interesting to note, continues to increase, the above-mentioned figure representing 23·4 per cent. of the total merchant shipbuilding tonnage in hand in this country. A year ago the motor-ships building numbered 48 and the aggregate tonnage of these vessels, viz., 221,274, accounted for 16½ per cent. of the total tonnage building at that time.

The foreign shipbuilding industry has also shown some signs of improvement during the June quarter, the total tonnage in hand in other countries having increased from 1,042,875 to 1,100,151 from March 31 to June 30. The new tonnage commenced abroad during the June quarter, viz., 243,974, was 40,154 tons higher than the corresponding figure for the March quarter, although the tonnage launched was lower, the figures for the March and June quarters being 188,738 tons and 163,666 tons, respectively. The tonnage upon which work has been suspended abroad has also increased during the June quarter from 118,000 to 140,000, so that work is now actually proceeding on about 960,000 tons as compared with 925,000 tons at the end of March. On the whole, the foreign shipbuilding industry certainly shows rather less signs of recovery than does the British industry. The most important contributions to the foreign total are those of Germany and Danzig 340,749 tons; France, 144,240 tons; Italy, 127,772 tons; United States, 103,665 tons; and Holland, 96,453 tons.

Motor-ships constitute an even larger proportion of the merchant tonnage building abroad than is the case for this country, there being 100 vessels of this type, with an aggregate tonnage of 455,065, in the hands of foreign shipbuilders. The tonnage figure given is over 41 per cent. of the total tonnage under construction abroad, and adding to this the corresponding figure for Great Britain and Ireland, previously mentioned, it appears that motor-ships now constitute no less than 31 per cent. of the world's shipbuilding work. The tanker tonnage in hand for the whole world, neglecting vessels of less than 1,000 tons, amounts to 180,170 comprised in 28 steamers and motor-ships, and, of this tonnage, 13 vessels, totalling 87,570 tons, are building in Great Britain and Ireland. We should point out, in conclusion, that the tonnage figures given above are gross in all cases and that, unless otherwise stated, all vessels of 100 gross tons and upwards are included in the statistics.

UNITED STATES IRON AND STEEL PRODUCTION.—The Guaranty Trust Company of New York state that the pig-iron production in the United States in May was 2,615,110 tons against 3,233,428 tons for April and 3,967,694 tons a year ago, the daily average being 84,358 tons against 107,781 tons for April and 124,764 tons a year ago. The steel ingot output in May was 2,628,261 tons against 3,333,535 tons for April and 4,216,355 tons a year ago.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig iron continues quiet, but the statistical situation is not unsatisfactory, and producers are showing marked determination to adhere at least to quotations that have ruled for a week past. Stocks at some makers, yards are rather considerable, but they are stated to be fully sold. Inquiries are a little better, but local and other home demand still falls a good deal short of what could be desired, and overseas trading continues to be hampered by Continental financial conditions. No. 1 Cleveland pig iron is scarce, and this quality commands quite 93*s.* No. 3 g.m.b. is reported none too plentiful, and is now difficult to purchase even from second hands at below 88*s.* Foundry 4 is put at 87*s.*, and No. 4 forge is quoted 86*s.*

Hematite.—Makers are rather pressing sales of East Coast hematite, buyers of which are backward, and values are still on the downward curve. Customers claim they can satisfy their needs at a little below 96*s.* 6*d.* for Nos. 1, 2 and 3, though that is the recognised market figure. No. 1 is quoted 6*d.* above mixed numbers.

Blast-furnacemen's Wages.—The average net selling price of No. 3 Cleveland pig iron for the quarter ending June 30 last, having been certified at 89*s.* 4·13*d.* per ton, as compared with 95*s.* 8·94*d.* per ton for the previous three months; blast-furnacemen's wages are reduced by 6·25 (6¼) per cent. for the second quarter of the year, lowering wages from 28 per cent. above the standard to 21·75 per cent. above the standard.

Foreign Ore.—There is little or nothing passing in imported ore, buyers and sellers differing a good deal in their ideas as to values. Consumers not being necessitated to purchase are holding off the market. Sellers still base quotations on best rubio at 23*s.* c.i.f. Tees.

Blast-furnace Coke.—Durham blast-furnace coke is, if anything, a shade firmer. Good medium qualities are 27*s.* 6*d.* delivered here, and some sellers are inclined to hold out for rather more.

Manufactured Iron and Steel.—Demand for galvanised sheets is unabated, and works are running at full pressure, some firms being so fully booked that they are having to turn down orders. The export price for 24-in. gauge sheets is firm at 18*l.* 5*s.* Nearly all other descriptions of manufactured iron and steel are slow of sale. Export quotations are matter of negotiation, but the following agreed figures are still adhered to for home business: common iron bars, 12*l.* 10*s.*; iron rivets, 14*l.* 5*s.*; packing (parallel), 9*l.*; packing (tapered), 12*l.*; steel billets (soft), 9*l.*; steel billets (medium), 10*l.*; steel billets (hard), 10*l.* 5*s.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge, and tank plates, 10*l.* 5*s.*; steel angles, 10*l.*; heavy rails, 9*l.*; and fish plates, 13*l.*

Imports to the Tees.—Interesting returns issued this week by the Tees Conservancy Commission show the quantities of iron and steel imported to the Tees ports from Holland, Belgium, France, Norway, Sweden, Germany, India, and coastwise for the eight months ending June last as compared with the same months of a year ago, and the corresponding pre-war period of 1913–14. Pig-iron brought in to the end of June last totalled 15,740 tons as against 5,557 tons a year ago, and 213 tons in the pre-war period; crude sheet bars, billets, blooms and slabs imported in the last eight months reached 50,560 tons, as compared with 49,881 tons a year ago, and 30,307 tons in the pre-war period; and plates, bars, angles, rails, sheets and joists unloaded to the end of last month amounted to 12,081 tons as against 8,549 tons a year ago, and 17,419 tons in the pre-war period.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Conditions have not materially altered during the past week, except to show a further slight reaction in some of the heavy steel branches. The usual mid-summer stocktaking operations give an appearance of depression that is not perhaps altogether warranted by the state of order books, though whether the big steel plants will have gathered sufficient new business in the interim to enable machinery to be restarted to the extent formerly obtaining is a matter for serious conjecture. Many of the leading furnaces and rolling mills have not only completed the bulk of the work secured six months ago in the face of keen competition from other districts in this country and from abroad, but have definitely proved much of this to have been unremunerative. Working costs are subject to all manner of additions since plants were extended. Business that pre-war would have shown a fair return has now to bear its share of standing charges incurred on departments that are operating only part time or are wholly idle. Rolling mills, particularly, are feeling the force of current depression, and are carrying on in spasmodic fashion. The outlook in regard to heavy engineering is slightly more hopeful than in the purely steel branches, though the two are to a great extent necessarily related. Railway and power unit contracts have done much to assist manufacturers over their recent difficulties, and as prices are exceptionally low the possibility of attracting some of the big business which is known to be pending on Colonial and foreign account is kept well in view. Meanwhile British mining and tramway requirements are reported to be on a slightly expanding scale, and now that the greater portion of stocks purchased during the war appears to have been worked out, users of special steels are coming rather more freely into the market for renewals. The lighter steel trades retain their more favourable position. Foreign competition has not sensibly declined, but the more careful cultivation of customers' needs in overseas markets is having a marked effect on current buying. For raw and semi-finished materials, the market is mainly flat. Prices are nominally unaltered. The effect of the new arrangement for controlling the price of blast-furnace coke supplies to inland furnaces on the basis of the ash and moisture content has yet to be demonstrated. It is regarded as introducing an interesting principle which is capable of considerable extension in the case of other classes of fuel.

South Yorkshire Coal Trade.—The market shows little change, apart from the fact that export inquiries are slightly more active. Supplies all round, despite the restriction of outputs, are more than equal to the demand. Deliveries to British railway companies for stocking purposes constitute the outstanding feature of the steam coal trade. Gas and electricity plants are only taking moderate quantities of the best grades. Secondaries are easy, with a weakening tendency. Metropolitan and district purchases of house coal are on a low scale, though gross deliveries are said to be about equal to the seasonal average. Quotations:—Best hand-picked branch, 34*s.* to 35*s*; Barnsley best Silkstone, 28*s.* to 29*s*; Derbyshire best brights, 28*s.* to 30*s.*; Derbyshire best house, 25*s.* to 27*s.*; Derbyshire best large nuts, 24*s.* to 25*s.*; Derbyshire best small nuts, 18*s.* 6*d.* to 20*s.* 6*d.*; Yorkshire hards, 23*s.* to 24*s.*; Derbyshire hards, 21*s.* 6*d.* to 23*s.* 6*d.*; rough slacks, 12*s.* 6*d.* to 15*s.* 6*d.*; nutty slacks, 12*s.* to 14*s.*; smalls, 8*s.* to 10*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—There has been little development in the Scottish steel trade this week, and the conditions are almost without change. Consumers are not ordering much for forward delivery, and the continuous running of the mills is a matter of difficulty at the steel works. In one or two instances there has been a slight increase in demand for material before the holidays in view of a lengthened stoppage. Ships plates are very quiet, but a fair amount of dealing has gone through in structural sections. Perhaps the brightest part of the industry is black sheets, which are moving very freely. The overseas demand continues good and some very satisfactory contracts have been secured, but the bulk of the business passing is for the lighter gauges, and heavy gauges are rather dull. Galvanised sorts are also in request and producers are very well employed. Prices all round are steady and are as under:—Boiler plates, 13*l.* 10*s.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, $\frac{1}{4}$ in. to $\frac{1}{2}$ in., 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—No improvement of any kind falls to be reported in the West of Scotland malleable iron trade. The securing of orders to keep the works going is a source of no little trouble at the present time, and the closing down for the holidays will to some extent be a relief to the managements. The export as well as the home trade has been extremely dull of late. Prices are being maintained at 12*l.* 10*s.* per ton for "Crown" bars, delivered Glasgow stations.

Scottish Pig-Iron Trade.—A quiet tone is very general in the pig-iron trade of Scotland, and the outlook is not very bright. Home consumers are not taking much at present and the export trade shows a decided falling off also. Hematite iron is in very poor demand, and the same can likewise be said of foundry grades, so that there will be no hurry to light up after the holidays unless there is a decided improvement all round. Prices are weak and are as follows:—Hematite, 5*l.* per ton, delivered at the steel works; foundry iron, No. 1, 5*l.* 3*s.* per ton; and No. 3, 4*l.* 16*s.* 3*d.* per ton, both on trucks at makers' yards.

Shipments of Scottish Pig Iron.—The shipments of Scottish pig iron from Glasgow Harbour continue on a low level. For the week ending last Saturday, July 5, the amount totalled 1,722 tons. Of that total 1,485 tons went overseas and 237 tons went coastwise. During the corresponding week of last year the figures were 1,011 tons on foreign account and 30 tons coastwise, making a total shipment of 1,041 tons.

THE FRANKLIN INSTITUTE, PHILADELPHIA.—On March 30, 1824, the Governor of the State of Pennsylvania signed an Act incorporating the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanical Arts, and the president, management and members of the Institute have resolved to celebrate the centenary of the signing of this Act by meetings on September 17 and the two succeeding days.

STAFF APPOINTMENTS FOR AIRSHIP DEVELOPMENT.—In connection with the Government scheme for airship development referred to on page 709 of our issue of May 30 last, the following staff appointments have been made:—Group Captain P. F. M. Fellowes, D.S.O., will be Director of Airship Development under the Air Member for Supply and Reserve (Sir Geoffrey Salmond); Squadron Leader R. B. B. Colmore will be Deputy-Director in Charge of Planning; Major G. H. Scott will be the Officer in Charge of Flying; and Mr. H. B. W. Evans, R.C.N.C., will be the Officer in Charge of Construction; Colonel V. C. Richmond will take charge of the Research and Design Section, and Mr. R. F. Hubbard has been appointed Works Manager at Cardington.

NOTICES OF MEETINGS.

THE INSTITUTION OF CHEMICAL ENGINEERS.—Wednesday, July 16, at 11 a.m. At the Hotel Cecil. Second Annual Corporate Meeting. Presidential Address by Sir Arthur Duckham, K.C.B. Sir Frederic Nathan will review the work of the Education Committee on "The Training of a Chemical Engineer." At 3.30 p.m., "Self-Balancing Centrifugals," by Mr. E. A. Alliott. "Evaporation in Currents of Air," by Mr. G. W. Himus and Prof. J. W. Hinchley. After the meeting there will be a visit to the British Empire Exhibition, Wembley.

THE PHYSICAL SOCIETY OF LONDON.—Saturday, July 19, Special Meeting at Cambridge. At 10.30 a.m. Visit to the works of the Cambridge and Paul Instrument Company. At 1 p.m. Lunch at Trinity College. At 2.45 p.m. Inspection of the Cavendish Laboratory. At 4.15 p.m. Meeting at the Cavendish Laboratory. "Radiations in a Discharge Tube," by Sir J. J. Thomson, O.M., F.R.S. "Recent Experiments on the Artificial Disintegration of the Elements," by Sir Ernest Rutherford, F.R.S, and Dr. J. Chadwick. "A Two-Dimensional Recording Accelerometer for Aeroplane Research," by Dr. G. F. C. Searle, F.R.S.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—A smaller quantity of coal was shipped from South Wales in June than in any previous month this year. The reduction was partly due to the fact that there were only 22 working days, owing to the intervention of the Whitsun holidays, and partly to the restrictive influence of the railway shopmen's strike. Shipments in June amounted to only 1,911,080 tons or 305,470 tons less than the average for the first five months of the year, and no less than 627,920 tons below the average for the corresponding period of last year. The average quantity shipped per working day in June was 83,090 tons compared with a daily average of 86,000 tons in May. All the ports shared in the retrogression, for shipments from Cardiff were reduced from 1,461,160 tons in June of last year to 1,109,690 tons in the past month; at Newport from 524,020 tons to 353,640 tons; at Swansea from 277,080 tons to 232,330 tons; at Port Talbot from 245,490 tons to 174,210 tons; and at Llanelly from 59,540 tons to 41,200 tons. Exports to France were reduced from 1,033,660 tons to 771,670 tons; to Italy from 437,920 tons to 181,700 tons; to South America from 348,530 tons to 249,830 tons; to Portugal from 114,900 tons to 58,400 tons; and to Germany from 91,360 tons to only 7,370 tons. Greece, on the other hand, took 54,770 tons against 39,630 tons, and the British coaling depots 164,980 tons against 130,010 tons. Meanwhile colliery salesmen experience difficulty in securing sufficient orders to keep the pits working regularly. The demand for smalls and sized coals in particular is very poor, with the result that sellers cannot supply the collieries with a sufficiency of empty wagons. Best steam smalls command no more than 17*s.* 6*d.*, and the inferior classes are available down to 14*s.* Best Admiralty large is fairly steady at 28*s.* to 28*s.* 6*d.*, but seconds are plentiful at 27*s.* 6*d.*, though in the Monmouthshire section best Eastern Valley large commands 26*s.*, the same as Western Valleys, with best Black Veins worth another 6*d.* The first audit for the Welsh coalfield under the new wages agreement gives a certified wage of 31·46 per cent. above the 1915 standard for July or 10·81 per cent. below the minimum of 42·22 per cent. The deficiency between the certified wage and the minimum has to be met by the coalowners out of their share of the surplus profits and standard profits. The coalowners are, in fact, compelled to sacrifice the whole of their surplus profits and also 428,529*l.* of their standard profits.

Iron and Steel.—Exports of iron and steel goods from South Wales last week amounted to 21,817 tons compared with 18,809 tons in the previous week. Shipments of tinplates and terneplates totalled 9,093 tons against 8,100 tons, blackplates and sheets to 8,511 tons against 3,314 tons, galvanised sheets to 2,510 tons against 4,873 tons, and other iron and steel goods to 1,702 tons against 3,522 tons.

LIVERPOOL CORPORATION TRAMWAYS.—The report of the general manager for the 12 months ending March 31, 1924, shows the following figures. Total operating costs per car mile, 16·222*d.*; interest and sinking fund per car mile, 1·383*d.*; total charges per car mile, 17·605*d.* renewals per car mile, 3·100*d.*; car mile earnings, 20·668*d.*; route mile earnings, 18,391*l.*; average fare per passenger, 1·565*d.*; length of track operated, 139·6 miles.

INTERNATIONAL MATHEMATICAL CONGRESS, TORONTO—The International Mathematical Congress will be held at Toronto, Canada, August 11 to 16, under the auspices of the Royal Canadian Institute and the University of Toronto. This is the first meeting of the Congress to be held on the American Continent. Special prominence will be given to the engineering and other practical applications of mathematics, and contributions have been invited from mathematical physicists and engineers engaged in mathematical investigations of engineering problems. The proceedings of the Congress will be printed, and it is hoped that they may form a complete contemporary account of the pure and applied mathematical sciences. Seventy scientific institutions on the American continent, and 90 in Europe and elsewhere have arranged to send one or more delegates. Additional information may be obtained from Professor J. L. Synge, Royal Canadian Institute, Toronto, Canada.

THE NEW GLADSTONE DOCK WORKS AT LIVERPOOL.

MR. THOMAS M. NEWELL, M.INST.C.E., ENGINEER-IN-CHIEF, MERSEY DOCKS AND HARBOUR BOARD.

(*For Description, see Page* 47.)

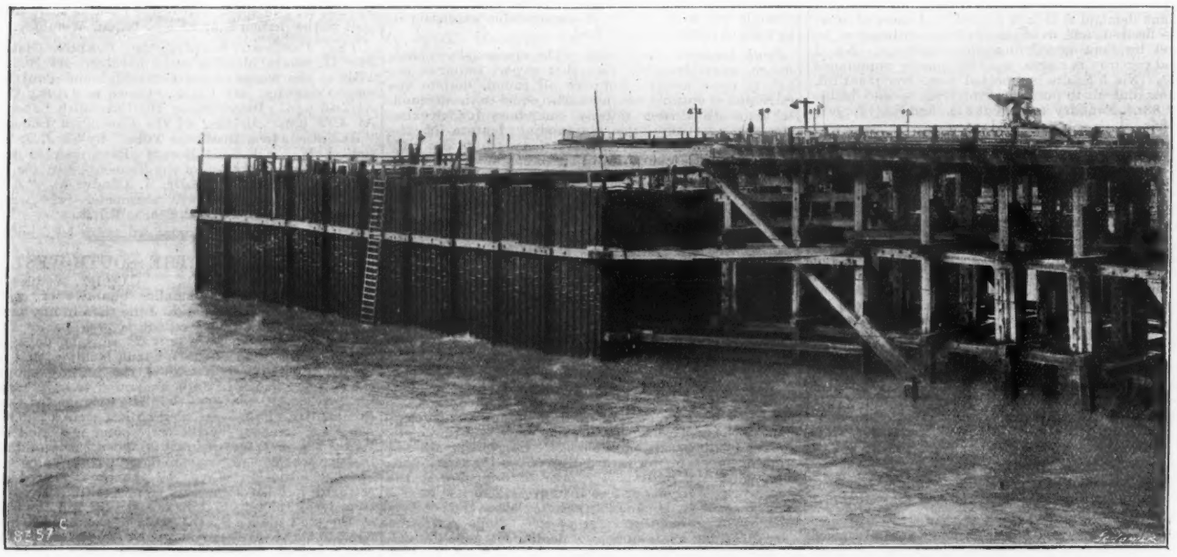


FIG. 13. OUTSIDE VIEW OF SHEET PILE DAM FOR EXTENSION OF RIVER WALL.

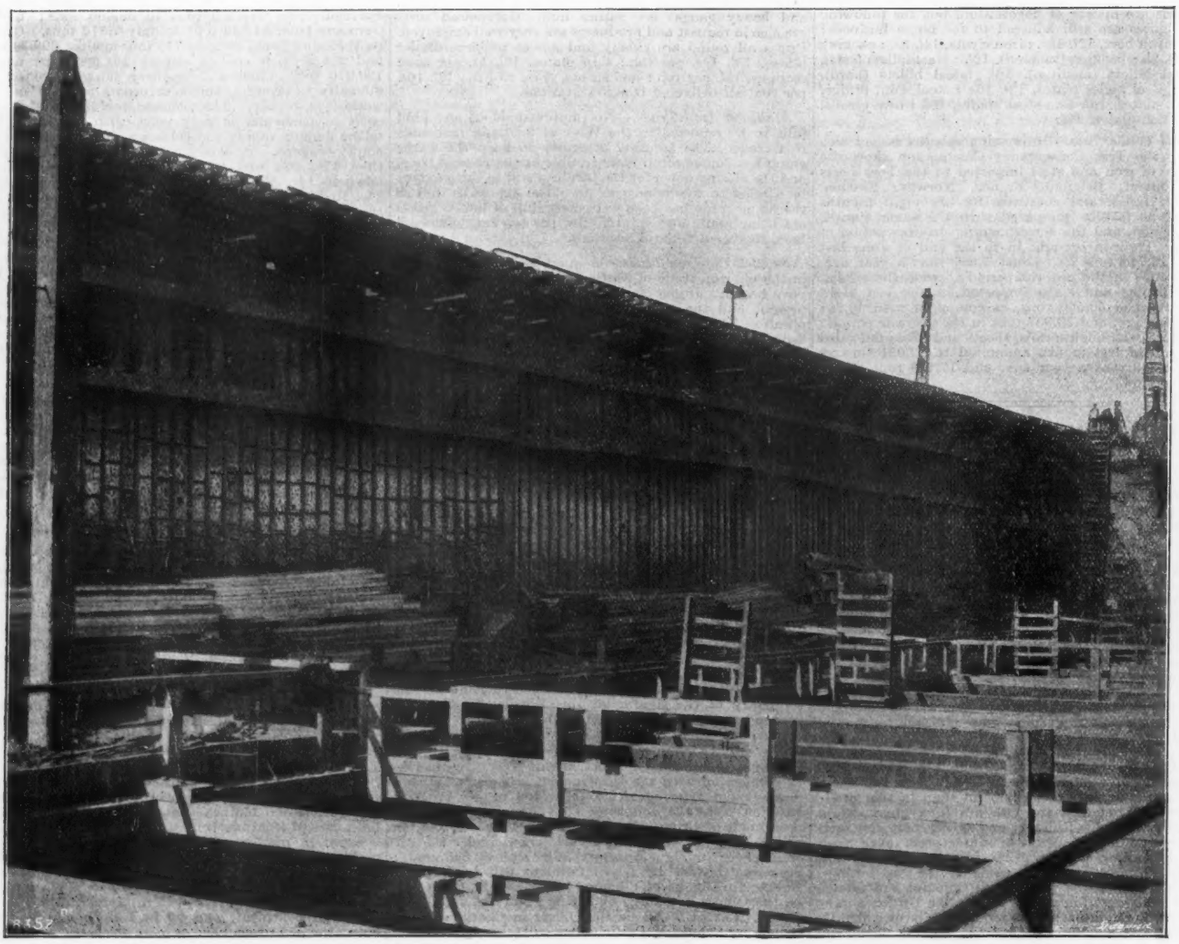


FIG. 14. INSIDE VIEW OF SHEET PILE DAM FOR EXTENSION OF RIVER WALL.

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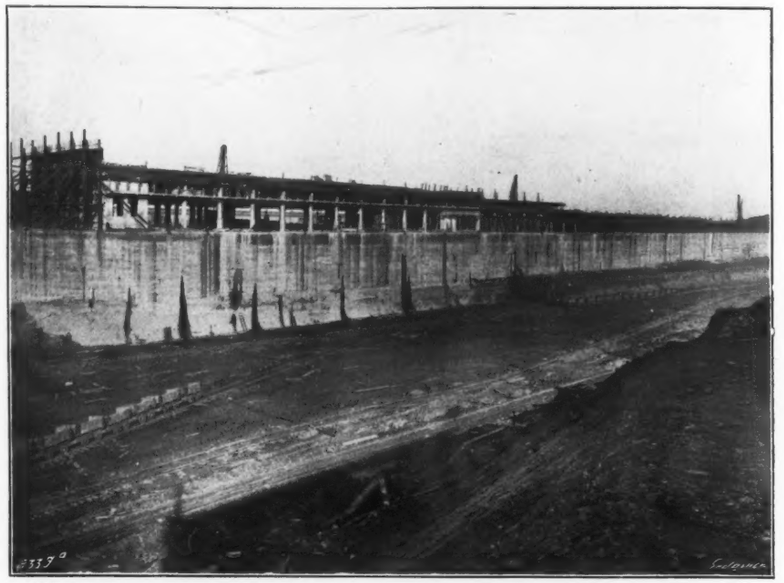
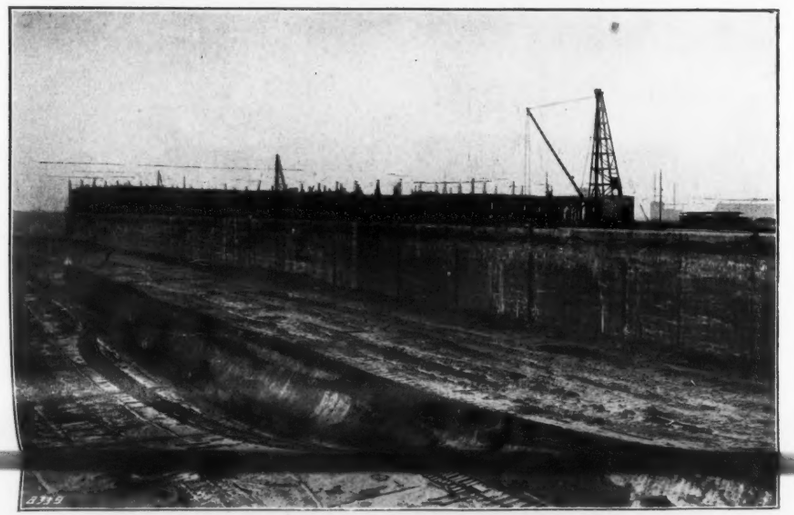


FIG. 5. BRANCH NO. 1, DURING EXCAVATION.

FIG. 6. BRANCH NO. 1, DURING EXCAVATION.



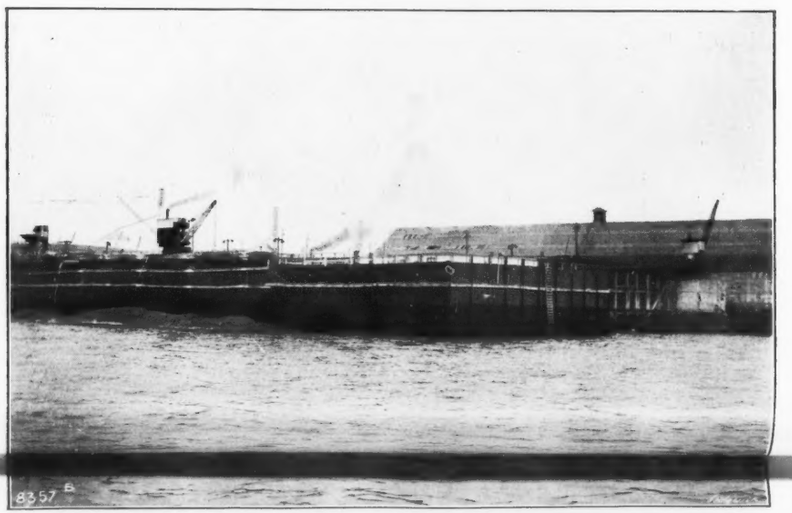


Fig. 7. Branch No. 1, During Excavation.

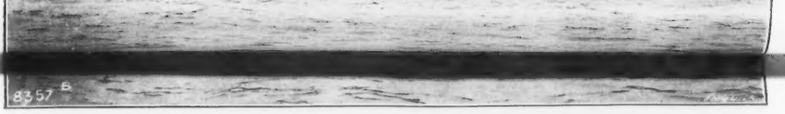


Fig. 8. Sheet Pile Dam Looking from River.

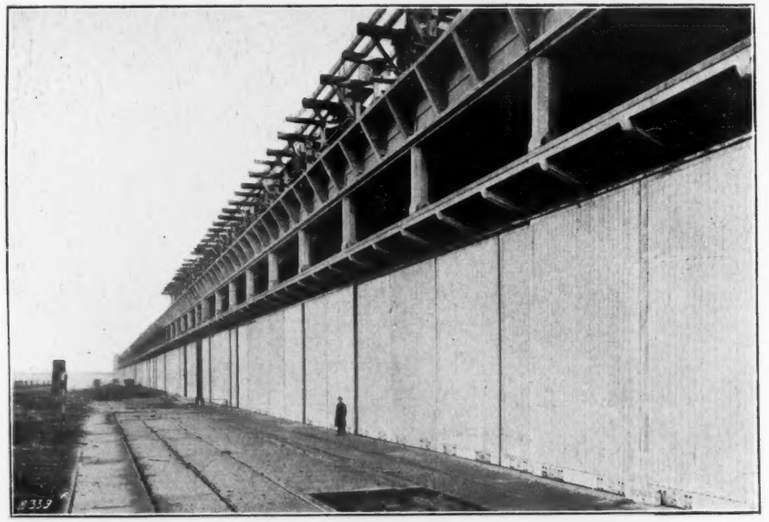


Fig. 9. Inner Face of Three-Storey Shed.

Fig. 10. Sheet Pile Dam During Construction.

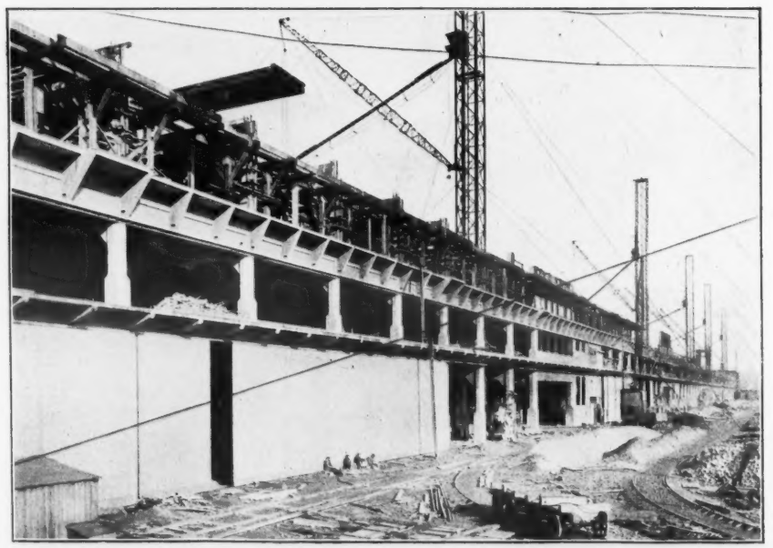


Fig. 11. Shed During Erection Showing Concreting Towers.

Fig. 12. Lock Gates During Erection.

ENGINEERING.

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received 10 days previous to the day of publication.

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Two-Page Plate.—THE NEW GLADSTONE DOCK WORKS AT LIVERPOOL.

ENGINEERING.

FRIDAY, JULY 11, 1924.

THE STANDARDISATION OF BOILER TESTING.

DURING the last twenty-seven years three separate committees have been appointed to try to devise some practicable code of rules in accordance with which boiler tests should be carried out. The aggregate time spent by these committees amounts up till the present to something like eleven years. It is difficult to believe that a single engineer properly conversant with the subject could not produce a reasonable code in about as many weeks. Certain decisions, however, must necessarily be entrusted to committees if they are to secure general acceptance, and the Committee on Heat Engine and Boiler Trials, comprising as it does four members from each of the nine Institutions concerned, in addition to representatives of various commercial interests, surely is equipped with all the eyes and hands postulated by Bacon as advisable for the wise and speedy completion of a great undertaking. It was appointed in September, 1922, and although its duties are concerned with boilers, gas-producers and heat engines of all kinds, engineers are looking to it more particularly to bring about some common practice with regard to boiler trials. The need for an authoritative pronouncement as to how boiler trials should be conducted, and what figures should be recorded, has been urgent for a long time and becomes more insistent every day. If the question were merely one of scientific interest it could be debated for ever without much harm, but it is, on the contrary, of the greatest commercial importance that some decision should be arrived at. No large boiler is now sold without guarantees as to its output and efficiency, and it is a most unsatisfactory state of affairs both to makers and users that test results of different boilers should not be on a strictly comparable basis.

The difficulty of the problem is indicated by the history of the attempts to provide a satisfactory solution. As long ago as 1897, on the suggestion of the late Mr. Bryan Donkin, the Institution of Civil Engineers appointed a Committee to deal with "Tabulating the Results of Steam Engine and Boiler Trials." It took this committee some five years to produce its final report, which appeared in 1902. This did not have a lengthy life, for in 1909 a new committee was appointed to bring it up to date. This work again occupied several years, the revised rules making their appearance in 1913 and constituting the standard Code of the Institution of Civil Engineers for Boiler Testing up till the present time. It is very much easier to criticise a code than to devise a satisfactory one, but it must be admitted that the code in question deserves a good deal of what has been said about it. It has, indeed, never commanded the respect of engineers, most of whom have simply ignored it on account of its impractical nature. The duty of the present committee is to replace it by something which shall be really useful to all those concerned with boiler efficiency, something that recognises the factors of the case in their true proportions, and provides a standard method of obtaining and stating results with as much accuracy as boiler-house conditions permit of.

In order to let it be known how the work of the Committee on Tabulating the Results of Heat Engine and Boiler Trials was progressing, a paper was read on July 3 before the Institution of Civil Engineers on the "General Scope and Objects of the Work of the Committee," by its chairman, Capt. H. Riall Sankey. A further object of the paper was stated to be to take advantage of the presence of overseas engineers attending the World Power Conference, for the discussion of a few debatable points. Four points only were explicitly raised, and on only one of them was their much likelihood of any decided difference of opinion. The first point was in connection with the use of the higher or lower calorific value of fuel. The last committee of the Institution of Civil Engineers declared that the lower calorific value ought to be adopted, and we are very glad to see that the present committee propose to reverse this decision. This should have been done long ago. Nobody at the meeting defended the views of the framers of the 1913 Code, and the use of the higher calorific value was unanimously endorsed.

In discussing calorific values, it is somewhat surprising that no one raised the question of how the moisture in the coal should be treated. The usual practice is to test dried samples for calorific value, and to call the calorimeter figure the "gross calorific value." If a tenth of the weight of the fuel put into the furnaces consists of moisture, as it frequently does, the "as fired" calorific value of the coal will only be nine-tenths that of the calorimeter figure, assuming the moisture to act merely as an adulterant to the fuel. Those who have burnt lignitic coals know that the moisture content is generally something like 25 per cent. to 30 per cent. of the weight of the fuel as fired, so that it is very important to have an authoritative ruling on this question. We believe that most practical engineers would agree that the proper figure to take is the "gross calorific value as fired," and that this value should be arrived at by correcting the figure given by the calorimeter in the proportion which the weight of the dried sample bears to its weight before drying.

The next subject upon which the opinion of the meeting was asked was the proposal of the Committee to omit from the Boiler Code the expression "lb. of steam evaporated from and at 212 deg. F." The object of the expression is, of course, to reduce all boiler outputs so far as possible to a common basis, so that a direct comparison can be made of the heat transmission in boilers producing steam at different pressures and temperatures and with various temperatures of feed water. The phrase is really equivalent to the quantity of heat passed through the heating surface per hour, 970 B.Th.U. being taken as the unit of transmission. One speaker suggested taking 1,000 B.Th.U. per hour as a "unit of evaporation" and another appeared very anxious to standardise the kilowatt-hour as a unit. This, of course, is equivalent to 3,412 B.Th.U. per hour, which is an awkward figure to manipulate. No vote was taken, so that it is difficult to be sure as to the consensus of opinion, but nobody seemed to object to the abolition of the expression referred to. As every alternative that was suggested recognised the fact that the question was one simply of expressing the rate of heat transmission in the best way, there is much to be said for simply replacing "lb. of steam evaporated from and at 212 deg. F." by "B.Th.U. transmitted per hour."

The meeting next turned to the consideration of

the fact that "The Committee does not propose to include the term "Boiler Horse-power." It will come as a surprise to most engineers that the use of the term should ever have crossed the minds of the Committee. As a phrase it means nothing, because the function of a boiler is to make steam, and the horse-power that the steam will develop depends upon the efficiency of the engine or turbine in which it is used. The term obtained currency in America at the time when reciprocating engineers required about 34·5 lb. of steam per hour per horse-power developed. Consequently a boiler which would produce 3,450 lb. of steam per hour was called a "boiler of 100 h.p." The term has persisted long after it had any correlation with reality, and as 3·45 lb. of steam per sq. ft. of heating surface was considered for many years a normal rating for a boiler, a "boiler horse-power" soon became the equivalent of 10 sq. ft. of heating surface. Hence as the term is used to-day, a 500 h.p. boiler means one with 5,000 sq. ft. of heating surface, and if it is evaporating 6·9 lb. of steam per sq. ft., it is said to be operating at 200 per cent. of its rating. Engineers in the United States are now giving up the term "boiler horse-power" and it would have been more than foolish if the Committee had authorised it over here. The slowly dying "Nominal horse-power" of agricultural and marine engines is quite bad enough, without further illogical units. No vote was taken at the meeting, but every speaker on the subject, American and English alike, seemed quite content that the term should fall into disuse as soon as possible.

The last and most contentious point of all, namely, whether water or steam meters were admissible in "comprehensive trials for scientific purposes," hardly obtained the discussion it deserved, because the meeting was brought to a close after about an hour. It is explained in an introductory paragraph to the paper that "the fundamental difference between trials for scientific and commercial purposes is that the former require the measurement of losses and the latter usually do not." A separate code is being prepared for each class of trial, and as nothing is said to the contrary, it may be taken that equal accuracy is assumed in both. The question then becomes whether water or steam meters may be used in any important boiler trial, commercial or scientific. Why instruments of any, and every, kind designed to measure water or steam should be stigmatised as more inherently unreliable than all the numerous weighing devices, wattmeters, pressure gauges, pyrometers, thermometers, &c., employed is not clear. Like all other measuring apparatus, they can be checked before and after the test, and to rule them out absolutely as the committee appear to be considering, is quite unjustified. To insist on weighing methods alone, is not only to render many trials too difficult or costly to be undertaken, but implies a pretence of accuracy in boiler trials which it is absurd to expect.

Every boiler trial of whatever kind and for whatever purpose involves a knowledge of the calorific value of the fuel. Even an eight-hour test on a large boiler may involve the combustion of 50 tons of coal, and the heat liberated by this quantity of fuel is supposed to be obtained by the combustion of a few thimblefuls in a calorimeter. It not only requires a considerable effort of faith to believe that the sample or samples taken can be relied on as typical of the carloads of coal they represent, but added to the sampling errors, are the inaccuracies of the calorimeter and of the man who operates it. The probable error in any determination of boiler efficiency is greater than the probable error of the coal analysis, and it is little use worrying about refinements of measurement of water or steam until the determination of the calorific value of coal is put on a much more satisfactory footing.

Should anyone doubt the justice of these remarks he is recommended to get three or four reputable analysts to take samples of the same carload of coal, and to compare the calorific results obtained. Even supposing the same sample is divided and sent to different laboratories, the results may be equally discordant. We have before us a set of ten tests made by experienced analysts in ordinary commercial work, showing that if the mean value of the figures obtained from the same sample is taken as the correct value, then errors amounting to nearly 5 per cent. are possible in the calorific value. The "probable error" in the mathematical sense, or the error which will be exceeded in half the number of tests and not exceeded in the other half, is 1·48 per cent. In other words, any calorific test taken at randon is just as likely to be more than 1·48 per cent. wrong, as it is to be within this degree of error. This, it must be remembered is when the different analysts are working on parts of the same sample. Had each analyst taken his own sample the discrepancies would have been many times greater. In view of facts like this, it is to be hoped that the Committee will lay down rules which will ensure that the calorific value shall be checked by more than one analyst, and that a sufficient number of determinations shall be made and averaged, to obtain the best approximation to the true value. The drawing up of such rules is not the least important work of the Committee, for until the calorific value of the fuel can be relied on as reasonably accurate, boiler test results will remain subject to the suspicion which at present surrounds them. If the deliberations of the Committee result in the production of a practical boiler-testing code without undue delay, their work will be of immense value to all engineers engaged in the manufacture and operation of boiler plant.

UNSOLVED PROBLEMS IN ELECTRICAL ENGINEERING.

THE knowledge and the ideas of any intellectual man cover such a variety of subjects and interests and, while definite enough in some spheres, shade off to such indefinite outlines that any process of intellectual stocktaking which will reveal clearly to him what he knows and what he does not know is practically an impossibility. By limiting his scope, however, he may with care and some trouble reveal to himself the actual state of his knowledge in some selected sphere. The average man certainly does not make a practice of any such stocktaking, but in the technical sphere he not infrequently finds it done for him. It is an exercise which forms a favourite subject for presidential addresses, in which the existing stage of development of some branch of industry or science is reviewed in a detail depending on the industry of the author. A variant on the theme is at times introduced by reference to the immediately proximate possibilities of advance, and many addresses dealing with "unsolved problems" in some branch of engineering have been prepared and delivered.

Previous contributions to the list of such omnibus addresses were added to on Tuesday last, when Professor Elihu Thomson delivered the James Forest lecture to the Institution of Civil Engineers. Professor Thomson took as his subject "Electrical Progress and its Unsolved Problems," thus claiming a sphere which covered the intellectual stocktaking to which we have referred, and at the same time enabling him to touch on some of the problems still awaiting solution in the sphere of work in which he occupies such an honourable position. The result was an address which all electrical men could read with advantage. The ramifications of electrical engineering now extend so far and into such alien matters that the whole range of its applications cannot fall within the practical experience of anyone, and a summary by a master covering most of the ground cannot but be of value in crystallising ideas and illustrating the developments of familiar ideas in unfamiliar fields.

It is neither possible nor necessary for us to attempt to follow Professor Thomson in his range from the lightning flash to the storage cell. The ground in general outline is familiar, and the value of the address lies in its summation of the best that has yet been done in the various parts of an activity which is now as wide as civilisation. The particular effect of the address could only be obtained by repeating it, and this in the circumstances of this week we are quite unable to find the space for. Without attempting in any way to follow, or even to mention, all the items of the lecture there are, however, certain parts of it which may be selected for comment or praise.

For the everyday engineer the "unsolved problems" part of the address might be expected to have particular attraction, and in this respect we must confess that Professor Thomson left us somewhat disappointed. A layman reading this address, on the impossible hypothesis that he could understand it, might pardonably suppose that electrical engineering presents few unsolved problems to worry about, but this is hardly a likely conditi on in a sphere of work of such magnitude and such every day advance. It is naturally difficult to define an unsolved problem in general terms. Large generators, motors and transformers have already been brought to such a stage of efficiency that it is not unreasonable to suggest that there are no important unsolved problems in connection with them. In a sense this is so, and as Professor Thomson pointed out, such unsolved problems as there are are largely concerned with matters of insulation.

It will not do, however, to suggest, because the efficiency of many electrical machines is so high, that they present no new problems and that their design may be taken as final. There are, for instance, two very definite lines of advance open to the designer of machines neither of which was, we think, referred to by Professor Thomson. There may naturally be others, but some occur to us as very immediate and obvious, although possibly one of them may be considered to have been lifted out of the region of unsolved problems in recent months. The most obvious concerns the speed control of three-phase motors. There are too many attempted ways of carrying out this control, and each of them has too many limitations for it to be suggested that there is no problem here. There are no doubt many cognate problems, and the recent appearance of the Transverter suggests that there may be quite new possibilities in connection with some of our most common methods. Until its appearance the problem of the production of extra high-tension direct current in quantities was an unsolved problem; and even if the Transverter may be considered to have met the condition there is still much to learn and much to do in taking advantage of the possibilities which this machine has introduced. The whole question of very high tension distribution by cables, which is sometimes necessary or desirable, still offers many problems for solution, as is sufficiently made evident by the changes from current practice proposed by Major A. M. Taylor in connection with his hexaphase system of alternating current transmission.

It may possibly be suggested that in bringing forward subjects of the kind we have been dealing with, we are approaching the question, not of unsolved problems, but of the possible lines of development of the future, which was, perhaps hardly Professor Thomson's subject. In our own defence, however, we must point out that at times he did not hesitate to touch on such possibilities, and in one quite definite case of an unsolved problem we find it difficult to agree with his verdict. Dealing with the development of the incandescent lamp up to its latest form, in the gas-filled lamp, he concluded, "It would seem now, looking into the future, that but little further advance in this field is to be expected." This is speculation about the future, but there is a very definite unsolved problem in connection with the matter. As Professor Thomson himself said, "Even at the best only a small percentage of the energy is represented by the light emission." This surely indicates an unsolved problem. The fact that the present lamp is such an advance on its carbon prototype is no argument that finality has been reached, and it would appear at least possible that more may yet be done in the direction of selective radiation. If we may say so, the electric lamp, with its remarkable history of development, appears a specially dangerous article to postulate as having reached its limit.

One class of electrical work in which there are many unsolved problems is that of wireless telegraphy and telephony. This is, no doubt, partly due to the remarkably rapid advance of practice in these spheres. As Professor Thomson pointed out, "a characteristic of our age is the comparatively rapid development in practice of the new discoveries of science," and it is doubtful if in any branch of activity this immediate application of theoretical results has been more striking than in

wireless. This matter is, however, also complicated by its dependence on, and relation to, atmospheric and even cosmic phenomena. An electrical machine can be tested, and its output and efficiency measured with an accuracy which can hardly be approached in any other kind of engineering work, since the various conditions and qualities concerned are so definitely known and the reliability of measuring instruments is so high. When one comes to wireless transmission, however, a step is made from the postulated and recorded into the unknown. Atmospheric interference and the phenomenon of "fading" are connected with influences outside the control of any designer, offering enormous difficulty to investigators. No doubt, in due course the accumulation and collation of data will enable the necessary conditions to be more satisfactorily met, but the whole subject still forms at least one electrical field which bristles with unsolved problems.

One of the branches of engineering work in which advance has been rapid and continuous over many years is that concerned with the manufacture of metals and alloys. This progress has had its full share of bearing on electrical advance, and, as Professor Thomson pointed out, the losses of power by eddy currents and hysteresis have been steadily reduced by advances in metallurgy. This is a field of such steady advance, however, that his expectations of still further progress are not surprising. The discovery of a permanent alloy which magnetically saturates in the earth's field alone, and the new cobalt steels for permanent magnets are suggestive of quite remarkable further possibilities in the bearing of metallurgical work on electrical engineering. Aluminium, which is still a comparatively new metal on a commercial scale, has not, perhaps, taken quite such a prominent place in electrical work as might have been expected. It, however, forms an admirable understudy to copper for very many applications, and it would require but a slight movement in relative prices for it to come into much more extensive use. It has not in general, we think, been used in actual electric machine construction, but Professor Thomson mentioned such an application for which it has been found advantageous. This was for the rotor conductors of squirrel-cage motors, for which purpose aluminium allowed of the cage being cast complete and in place without any joints. Mechanically this would appear to be an attractive method of construction, but we hardly follow Professor Thomson when he suggests that the lower conductivity of the aluminium as compared with copper is "of advantage in the process of starting such induction motors." If it is an advantage to increase the resistance of the rotor, surely it can be done even when copper is used by reducing the size of the conductors, and incidentally saving money.

THE NORTH TEES POWER STATION.

(*Continued from page 755 of previous volume.*)

HAVING given in our previous article a general description of the North Tees station, with particulars of its lay-out and equipment, we will now consider the design from the thermodynamic point of view. The advances in practice which have been embodied in the North Tees plant will be best appreciated by comparing this station with the Carville "B" station, which so long held the record for economy. The comparison is the more interesting in view of the fact that both stations have been designed by Messrs. Merz and McLellan—Carville "B" in 1913 and North Tees in 1917—so that such changes as have been made are in no way due to the diverging views of different engineers. Both stations, indeed, have one feature in common—namely, that each, when constructed, represented a step in advance of current practice, the boldness of the step in the case of North Tees giving that plant a very special interest. The success of Carville is a matter of common knowledge, and no person in a position to judge has any doubt that even more striking results will be obtained at the newer station as soon as the local industrial conditions are such as to provide an adequate load for it.

The feed-heating arrangements at North Tees are shown diagrammatically in Fig. 10, which also indicates the re-heating connections. Referring first to the latter, it will be seen that the steam leaving the high-pressure cylinder can be by-passed if desired direct to the low-pressure cylinder without passing through the reheater. Provision is also made for by-passing this steam direct to the condenser. This is done automatically in the event of the turbine suddenly losing its load, for it is evident that without some safeguard of this sort, the presence of a large quantity of superheated steam at 65 lb. pressure, out of control of the governor could do enough work in the low-pressure cylinder to cause the machine to race dangerously. Some of the high-pressure exhaust, before re-heating, is drawn off through a 7-in. connection to a Weir feed-heater, in which the third and final stage of the feedwater heating is accomplished, the water leaving this heater at a temperature of 300 deg. F.

The path of the condensate through the various heaters can be readily followed from the diagram. The extraction pump delivers it from the condenser to a hot-well. It is drawn thence by a lift-pump and delivered through a heater where it picks up the heat from various drains. It passes on through another heater to which the steam coming out of the glands is connected, and thence to the first of the three main heaters. This receives steam at 5 pounds absolute pressure from the low-pressure turbine. The water next passes through the intermediate heater, which is heated by steam at higher pressure, and finally back through the auxiliary heaters as shown to the suction of the boiler feed pump. This pump normally delivers it through the Weir pressure heater already referred to, to the boilers. This heater can be by-passed if desired, and indeed the whole of the feed-heating arrangements can be short-circuited and water delivered direct from the hot-well to the boilers in emergency, by manipulating the appropriate valves.

To facilitate the comparison between the two stations, we give in Table I a summary of the principal facts relating to the generating units in the respective plants.

It will be noted from the table that the steam-pressure has been increased from 250 lb. to 450 lb., and the vacuum from 29 in. to 29·25 in., the North Tees station thus using steam which exceeds both the higher and the lower limits of the heat-drop tables published in 1917 by the British Electrical and Allied Manufacturers' Association. The adiabatic heat drop at North Tees is 487·5 B.Th.U., and that at Carville is 442·6 B.Th.U., but no direct comparison on this basis is possible because of the different cycles employed in the two cases. All that can be fairly said is that if the Carville steam pressure and vacuum were increased to the North Tees figures, the cycle remaining the same as at present, the efficiency of the Carville cycle would be raised from 34·4 per cent. to 37·6 per cent. The difference between this and 40·7 per cent. is therefore the gain in cycle efficiency due to re-heating the steam and heating the feed-water by stages, as is done at North Tees. The actual benefit gained by re-heating the steam is greater than the improvement of the cycle which it causes, for reasons which will be referred to later and the benefit accruing from this cause is taken into account in the last two entries in the table.

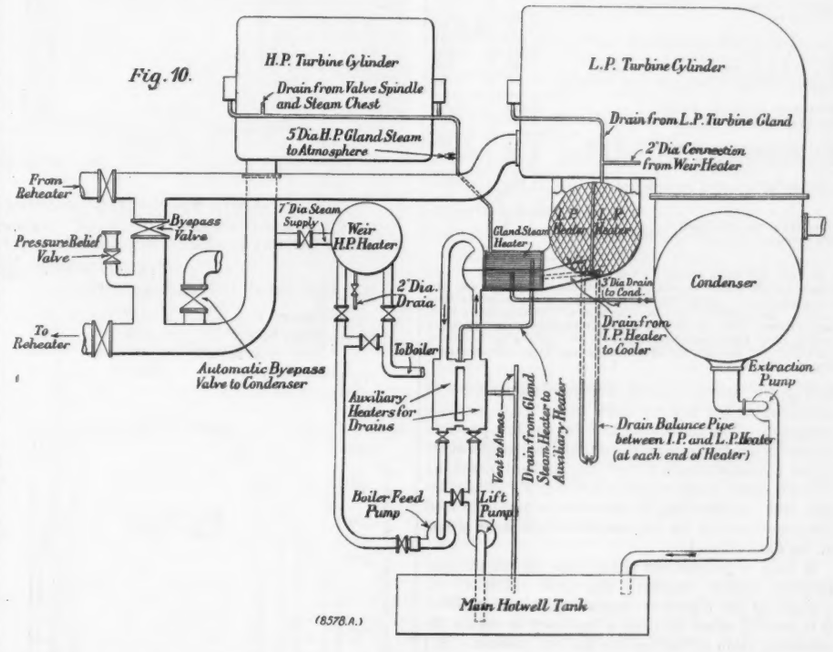
The ideal heat cycle for an engine is one in which the whole of the heat is put into the working fluid at the highest temperature that can be safely used and the whole of the rejected heat is disposed of at the lowest practicable temperature. These conditions are characteristic of the Carnot cycle. If such a cycle were possible, the conditions at Carville would

TABLE I.

	Carville "B."	North Tees.
Normal rated capacity of turbo-alternators .. k.w.	11,000	20,000
Speed of turbo-alternators r.p.m.	2,400	2,400
Steam pressure (gauge) at stop valve .. lbs. per square inch	250	450
Steam temperature at stop valve .. .. deg. F.	650	650
Condenser vacuum (bar = 30") ins. Hg.	29	29·25
Re-heating of steam	None	To 500 deg. F. at 65 lbs. gauge.
Feed water heating	None	To 300 deg. F. in three stages
Steam consumption (see note) lbs. per k.w.-h.	10·35 Test.	9·85 Computed.
Efficiency of heat cycle per cent.	34·4	40·7
Efficiency ratio of turbo-alternator .. .. per cent.	74·2 Test.	75·5 Computed.
Overall thermal efficiency of turbo-alternator to vacuum temperature .. per cent.	25·5	30·7

Note to Table I: The steam consumption given for the Carville turbo-alternators is an actual test figure, corrected to the nominal steam and vacuum conditions of the station. It is somewhat better than was guaranteed by the makers of the machines. The corresponding figure given for North Tees is calculated from the guaranteed efficiency of the machines, and is not based on a test. One stage of feed-water heating to 165 deg. F. has been provided for at Carville, and has since been put into commission. It is estimated that the overall efficiency of the turbo-alternator is improved to 26·4 per cent. by this change.

Fig. 10.



permit of a limiting or "Carnot" efficiency of 51·3 per cent., and at North Tees of 52·3 per cent. It is not, of course, possible to put all the heat into steam at the highest temperature, which in both the stations we are considering is 650 deg. F. At Carville "B" the average temperature at which heat is given to the steam is 364 deg. F., but in North Tees an average temperature of 440 deg. F. is attained. The different conditions and temperatures at which heat is imparted to the steam at the respective stations are shown in Table II. The increase in the steam pressure from 250 lb. to 450 lb. per square inch raises the boiling temperature from 406 deg. F. to 460 deg. F., and it will be seen at once that the average temperatures at which water is heated, evaporated and superheated are all therefore raised and the efficiencies of the processes increased accordingly. Progressive feed-water heating to 300 deg. F. by bleeding the turbine, &c., and without the addition of any new heat, raises the average temperature at which the water is heated in the boiler to a point about midway between 300 deg. F. and 460 deg. F., or 383 deg. F., instead of midway between 90 deg. F. to 460 deg. F.

When the steam is reheated after leaving the high-pressure cylinder of the turbine, fresh heat is added at an average temperature approximately midway between the temperatures at which the steam enters and leaves the reheater. There is a gain in the cycle efficiency if this average temperature of reheating is higher than the average temperature at which the original steam is made and superheated. At North Tees, owing to the impossibility of getting steel castings for the low-pressure turbine cylinder during the war period the average temperature of reheating is too low to show much gain in cycle efficiency. The use of cast iron for the low-pressure cylinders made it necessary to limit the temperature of the reheated steam to 500 deg. instead of raising it to the upper temperature of 650 deg. F. The chief gain due to reheating is therefore in the improved efficiency ratio of the turbine due to the drier steam at the exhaust end.

TABLE III.—*Calculated Thermal Efficiencies.*

	Carville "B."	North Tees.
Thermal efficiency of turbo-alternator (see Table I)	25·5	30·7
Useful heat per kilowatt-hour sent out	B.Th.U. 3,412	B.Th.U. 3,412
Heat rejected to condenser	9,784	7,484
Heat lost in alternator (at 5 per cent.)	180	180
Turbine mechanical losses (at 1 per cent.)	36	36
Heat input to turbine steam	13,412	11,112
Heat lost in boiler (at 15 per cent.)	2,369	1,961
Heat input to boiler (higher C.V. of fuel)	15,781	13,073
Heat lost in auxiliaries, &c. (at 20 per cent.)	3,950	3,268
Total B.Th.Us. in fuel per unit sent out	19,731	16,341
	Per cent.	Per cent.
Overall thermal efficiency	17·3	20·9
Improvement in North Tees over Carville	—	20·8

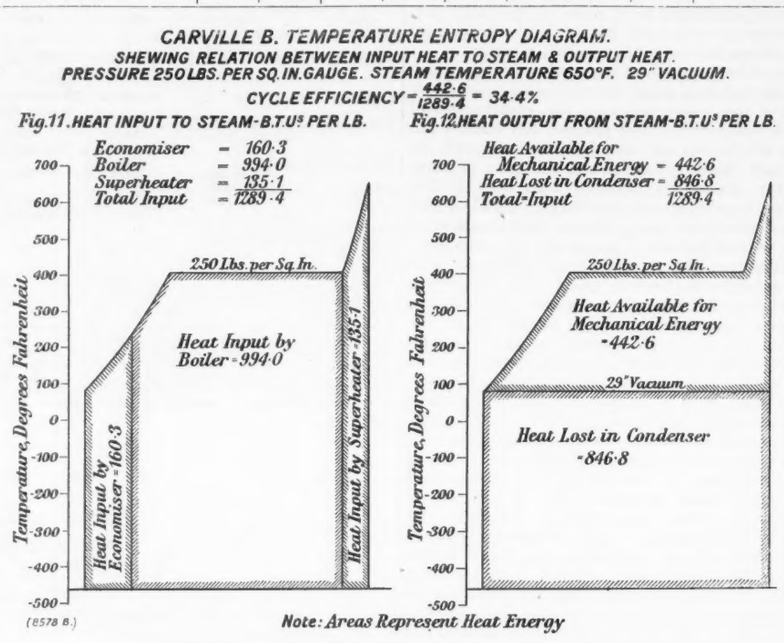
NOTE.—The calculations for Carville "B" are based on test values for the efficiency ratio of the turbo-alternators and the boiler efficiency. Those for North Tees are based on guaranteed figures. Assumptions as to auxiliary and operating losses have been made in both cases. Variations in operating conditions, of course, affect these figures appreciably, and, indeed in the case of Carville "B" the calculated efficiency has been corrected from time to time.

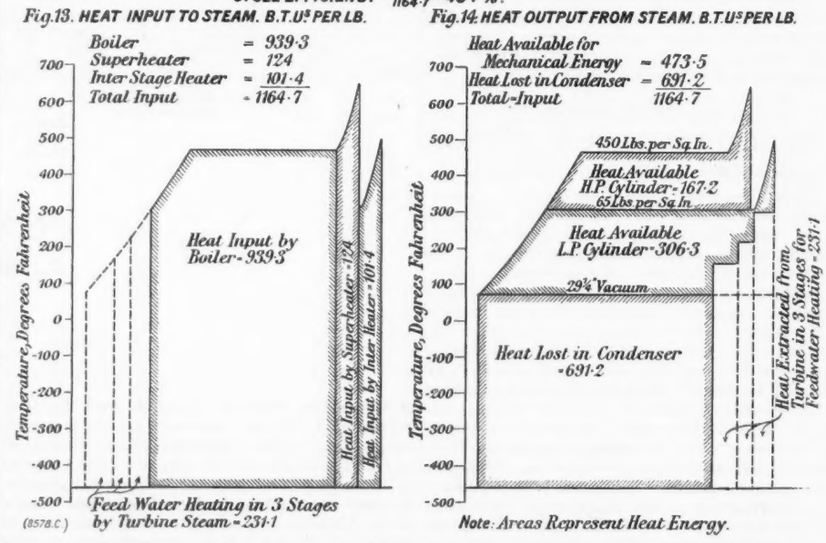
The improvement in North Tees over Carville from the thermodynamic point of view is shown most strikingly by the entropy diagrams, Figs. 11 to 14, annexed, which have been prepared by Mr. W. T. Bottomley of Messrs. Merz & McLellan's staff, who has been closely associated with the advanced thermodynamic design of North Tees. The first pair relate to Carville. Fig. 11 shows graphically the quantities of heat put into a pound of the Carville steam by the economiser, boiler, and superheater respectively. Of the total input of 1,289·4 B.Th.U., the economiser contributes 160·3 B.Th.U., the boiler 994 B.Th.U. and the superheater 135·1 B.Th.U. Fig 11 shows how this heat is disposed of on the Rankine cycle, 846·8 B.Th.U. being rejected to the condenser, and the remaining 442·6 B.Th.U., or 34·4 per cent of the total, being available for mechanical work on the turbine.

We may now turn to the corresponding diagrams for North Tees, Figs. 13 and 14. There are no economisers at North Tees, the feed heating being done by the steam itself. The area to the left of Fig. 13, shown in dotted lines represents the heat used for this purpose, amounting to 231·1 B.Th.U. per lb. The boilers receive the feedwater at 300 deg. F. and add a further 939·3 B.Th.U. of heat per lb., which results in the production of saturated steam at 450 lb. per square inch. It will be noticed that the boilers actually do less work to every pound of water passing through it than is done by the Carville boilers, but, other things being equal, more water would have to be evaporated by

TABLE II.

Stage of Heating.	Water.		Wet Steam.		Superheated Steam.		Re-heated Steam.		Total.	
Power station	Carville "B."	North Tees.	Carville "B."	North Tees.	Carville "B."	North Tees.	Carville "B."	North Tees.	Carville "B."	North Tees.
Per cent. of total heat in steam	25·8	14·5	63·7	66·2	10·5	10·6	—	8·7	100	100
Temperature range, deg. F.	90–406	300–460	406	460	406–650	460–650	—	378–500	90–650	300–650
Average temperature at which heat taken in deg. F.	238	383	406	460	516	552	—	436	364	440




NORTH TEES. TEMPERATURE ENTROPY DIAGRAM.
PRESSURE 450 LBS. PER SQ. IN. GAUGE. STEAM TEMPERATURE 650°F. 29¼" VACUUM.
REHEAT AT 65 LBS. PER SQ. IN. GAUGE TO 500°F. 3 STAGES FEEDWATER HEATING TO 300°F.
CYCLE EFFICIENCY = 473·2/1164·7 = 40·7 %.
Fig. 13. HEAT INPUT TO STEAM. B.T.U.s PER LB.
Boiler = 939·3
Superheater = 124
Inter-Stage Heater = 101·4
Total Input = 1164·7
Heat Input by Boiler = 939·3
Heat Input by Superheater = 124
Heat Input by Inter-Heater = 101·4
Feed Water Heating in 3 Stages by Turbine Steam = 231·1
Temperature, Degrees Fahrenheit
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
(8578 C.)
Fig. 14. HEAT OUTPUT FROM STEAM. B.T.U.s PER LB.
Heat Available for Mechanical Energy = 473·5
Heat Lost in Condenser = 691·2
Total Input = 1164·7
450 Lbs. per Sq. In.
Heat Available H.P. Cylinder = 167·2
65 Lbs. per Sq. In.
Heat Available L.P. Cylinder = 306·3
29¼ Vacuum
Heat Lost in Condenser = 691·2
Heat Extracted from Turbine in 3 Stages for Feedwater Heating = 231·1
Note: Areas Represent Heat Energy.

EXHIBITS AT THE ROYAL AGRICULTURAL SHOW AT LEICESTER.

CONSTRUCTED BY MESSRS. JOHN FOWLER AND CO. (LEEDS), LIMITED, ENGINEERS, LEEDS.

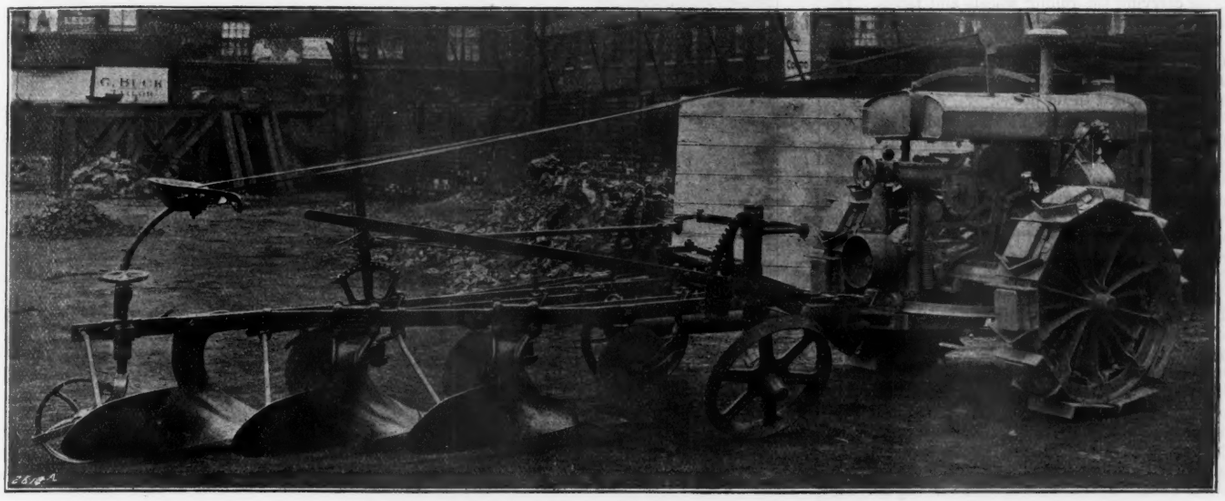


FIG. 8. REIN-DRIVE TRACTOR AND PLOUGH.

the North Tees boilers because some of the steam is used for feed-heating. The superheater increases the temperature to 650 deg. F., adding 124 B.Th.U. per lb. in the process, and the steam then goes to the high-pressure turbine. It expands in this turbine down to 65 lb. per square inch, its temperature falling to 378 deg. F. after allowing for the losses carried over from the previous stages. This is well above the saturation point, so that there is superheat, with all its advantages, throughout the high-pressure turbine. Reference to Fig. 14 will show that 167·2 B.Th.U. are rendered available for work by this expansion. The steam is now returned to the boiler-house and reheated to 500 deg. F., receiving an addition of 101·4 B.Th.U. per lb. in the process. It then goes back to the low-pressure turbine, the greater part of it giving up its heat in doing useful work, but some being withdrawn at three different pressures for feed-heating. Altogether the steam has had 1,164·7 B.Th.U. of fresh heat given to each pound of it, of which 691·2 B.Th.U. is rejected to the condenser, leaving 473·5 B.Th.U. available for mechanical work in the two turbines. Thus 40·7 per cent. of the total heat is available for work, this being the efficiency of the cycle. The low-pressure turbine develops 306·3 B.Th.U. from rather less than a pound of steam, as some is tapped off for feed-heating, and returns 231·1 B.Th.U. to the feed-water.

It should be mentioned that the figures given in this article are based on Marks and Davis steam tables, which were in general use until recently. The less convenient, but more accurate, tables by Callendar now used give heat-drops fractionally greater than those taken in the article.

We give in Table III a comparison of the calculated commercial overall efficiencies of Carville "B" and North Tees Power Stations together with a summary of the heat losses in the two cases.

We desire to acknowledge our indebtedness to Messrs. Merz and McLellan the designers of both the Carville and the North Tees power stations, and to their technical staff for information with regard to these noteworthy plants, also to the Newcastle-upon-Tyne Electric Supply Company for permission to publish the description of their North Tees station.

THE "TOPLIS" LUFFING CRANE.—Messrs. Stothert & Pitt, Limited, Bath, inform us that the resignation of their chief engineer, Mr. C. M. Toplis, will not affect the manufacture of their patent horizontal luffing cranes ("Toplis" patents), the sole interests and any subsequent improvements in the patents being assigned exclusively to them.

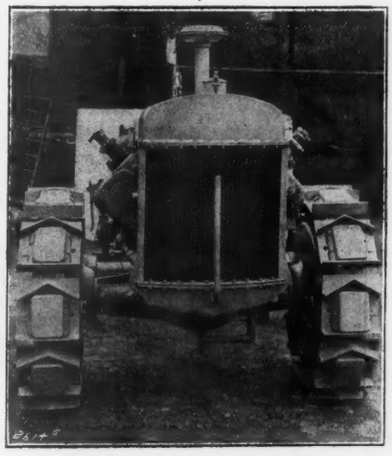


FIG. 9. FRONT VIEW OF REIN-DRIVE PLOUGH.

THE ROYAL AGRICULTURAL SHOW AT LEICESTER.

(*Concluded from page* 23.)

WE referred last week to the Rein-drive tractor exhibited by Messrs. John Fowler & Co., Ltd., of Leeds, and we are now able to illustrate this interesting machine in Figs. 8 and 9, above. In the former illustration the tractor is shown attached to a plough, though, of course, it may equally well be applied to any other implement. The driver, as will be seen, sits at the rear of the plough and controls the tractor by means of a pair of leather reins only. An appropriate movement of his wrist or arm is quite sufficient for starting, stopping, reversing or steering the vehicle, his right hand being completely free all the time for any desired manipulation of the plough. The ease of control was demonstrated at the Royal Show by allowing any person interested to test it himself, when it was evident how readily the machine responded to the reins and with what ease it could be manœuvred. The tractor, which has two road-wheels only, is rigidly coupled to the vehicle it has to pull, a telescopic tubular drawbar permitting of ready attachment to any implement. The main frame and gear-box is composed of a single casting, so that permanency of alignment is assured and a two cylinder V-type engine running on paraffin and giving 30 b.h.p. at 1,000 r.p.m. is mounted crosswise behind the radiator. The cylinders are 5½ in. bore by 7½ in. stroke and the single throw crankshaft is carried on ball bearings, the big end of the connecting rod working on roller bearings. The tractor has automatic lubrication throughout, the only attention this requires being the daily replenishment of the oil tank. All parts of the engine are continuously fed with fresh oil by a multiple force-feed pump, the oil never being used again, so that the trouble often experienced in paraffin engines due to the dilution of the crank-case oil with paraffin is entirely eliminated. The cast-steel tractor wheels are 40 in. diameter and 11 in. broad. They are fitted with removable traction pads, and the whole design is such that the wheel rolls over these pads on the ground, with the result that the intensity of pressure on the earth is much less than would be due to the wheels alone. The tractor is supplied with a trailing truck, running on two 30 in. wheels of ordinary design, and capable of carrying a load of 2 tons. Considerable experience has been gained in the use of the Rein-drive tractor in Australia where the design originated, and it appears likely to meet the conditions in this country equally well.

Messrs. Barford & Perkins, Limited, of Peterborough, who were, we believe, the original makers of motor-rollers, showed a large variety of these machines at Leicester, ranging from small ones suitable for lawns and cricket pitches to those equal to the heavier road-work. One of the firm's 12-ton rollers, similar to that illustrated in Fig. 10 on page 60, was on the stand. The back rollers are 66 in. diameter by 19½ in. wide and the front roller is 48 in. diameter by 50 in. wide, a width of 6 ft. 9 in. being rolled on each passage of the machine. The wheel-base is 9 ft. 10 in., the overall length 18 ft. 1½ in. and the height 9 ft. 3 in. over the awning. In addition to the natural weight of the machine water-ballast of 2 tons 12 cwt. can be carried. Power is provided by a four-cylinder petrol or paraffin engine, having cylinders 120 mm. bore by 140 mm. stroke, developing from 35 b.h.p. to 40 b.h.p. Rolling can be done either at 1¼ miles or 2¾ miles per hour in either direction, and there is in addition a forward travelling speed of 4 miles per hour. The fuel tank has a capacity of 50 gallons, and a water sprinkling tank holding 120 gallons can be furnished as an extra, with sprinkling pipes to the front and back rollers. A scarifier can also be fitted, as shown in the illustration, and to make the machine more generally useful a pulley can be

fitted to drive a stone-breaker or other machinery, and spring drawbars to enable loads to be hauled from the front or back of the roller. A feature of particular interest is the arrangement of the whole of the transmission gear, engine and radiator on a separate sub-frame, which is bolted to the main frame carrying the rolling wheels and tanks. The sub-frame can be lowered and pulled out backwards when a thorough examination or extensive overhaul of the machinery is required, and the engine and gearing can be tested in this position before the sub-frame is returned to its place.

The exhibit of Messrs. Fielding and Platt, Ltd., of Gloucester, consisted of three horizontal four-cycle, single-cylinder oil engines rated respectively at 16, 30, and 52 brake horse-power. All these engines are of the type illustrated in Fig. 11. The makers have concentrated their attention upon the hot-bulb, low-compression type of engine in preference to the high-compression, cold-starting design, holding that for ordinary users the advantages of a moderate cylinder pressure both in respect of ease of starting and lowness of maintenance, more than outweigh the slightly greater economy claimed for the rival type. The Fielding engines of the single-cylinder pattern are built in eight standard sizes ranging from 16 brake horse-power at 330 r.p.m. to 100 brake horse-power at 210 r.p.m., and twin engines from 128 to 200 brake horse-power are also supplied. The largest engine exhibited at Leicester developed a maximum of 52 brake horse-power at 240 r.p.m. with a cylinder 12½ in. bore by 22-in. stroke. Like the other engines of its design, it could be started in about two minutes from cold and would use as fuel the cheapest oils up to 0·95 specific gravity. The simplicity and reliability of engines of the type in question has brought them into extended use for the supply of power to small works, even in districts such as Birmingham, where they have to compete with a cheap and abundant supply of electricity.

We mentioned last week a new type of cold-starting crude-oil engine exhibited by Messrs. Blackstone and Co., Limited, of Stamford, which was noticeable on account of the nature of the fuel-injection gear employed. This gear we are now able to illustrate in Figs. 12 and 13, on page 61. The engine, as will be gathered from the drawings, is of the horizontal single-cylinder, open type. A small disc-crank, the pin of which is provided with angular adjustment, is attached to the end of the lay shaft and causes the continuous oscillation of the rocking lever A. A roller on this lever works in contact with the hardened-steel cap B, the inward motion of which compresses the stiff spiral spring seen in Fig. 12, and so tends to force the plunger C forward. The front end of the plunger C is in contact with fuel oil which is trapped between the ball inlet-valves and the spraying valve D, and the plunger therefore cannot move until the spraying valve is opened. On the rocking lever A is an abutment, which at the forward end of the travel of the lever comes into contact with a pin E, as shown in Fig. 12. This pin is forced inwards, thus counteracting the pressure of the spring F, which otherwise holds the injection valve D, closed through the medium of the levers shown in the plan, Fig. 13. An almost insignificant movement of E is sufficient to release the injection valve, when the fuel is suddenly injected by the action of the spring on the plunger C. On light loads the governor does not permit the fuel pump to force so great a quantity of oil in front of the plunger C, so that the plunger has a shorter travel, and the injection does not last so long. The moment of injection is however, unaltered, as this is determined by the contact of the lever with the pin E. It will also be noted that the force with which the oil is injected, being dependent only on the action of the plunger spring, will not vary with the speed of the engine, and a proper spray will therefore be obtained from the moment of starting the engine. The compression pressure on these engines is 350 lbs. per square inch. The Blackstone "spring injection" engines of the single-cylinder type are built in sizes from 4 to 150 brake horse-power, while by multiplying the cylinders powers up to 900 brake horse-power are provided. In all these engines starting is effected directly from the cold condition. The smaller sizes can be turned off by hand, but larger engines are got away with compressed air from containers, which are charged automatically from the engine cylinder when the engine is at work.

EXHIBITS AT THE ROYAL SHOW AT LEICESTER.

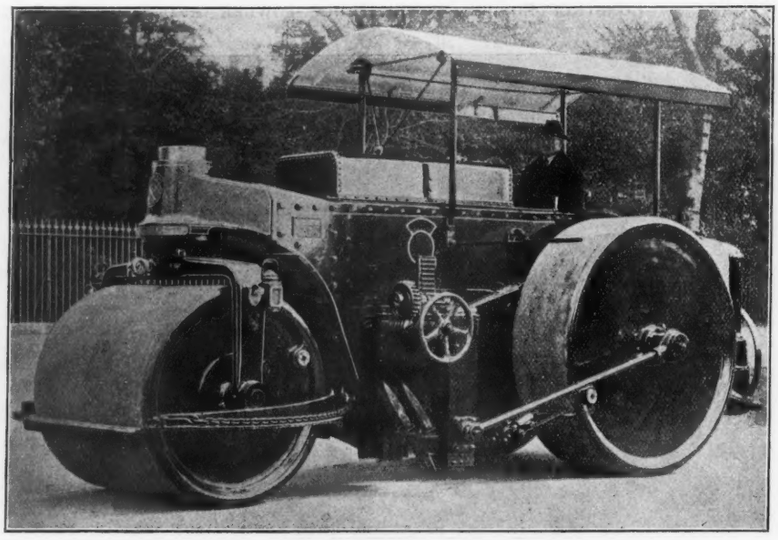


FIG. 10. 12-TON MOTOR ROLLER AND SCARIFIER; MESSRS. BARFORD AND PERKINS, LIMITED, PETERBOROUGH.

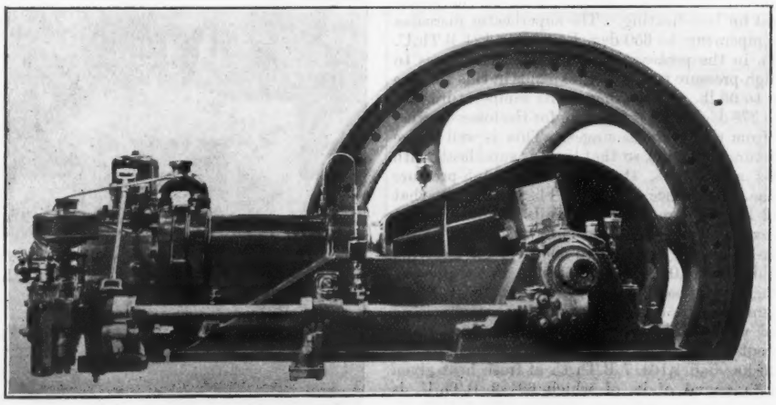
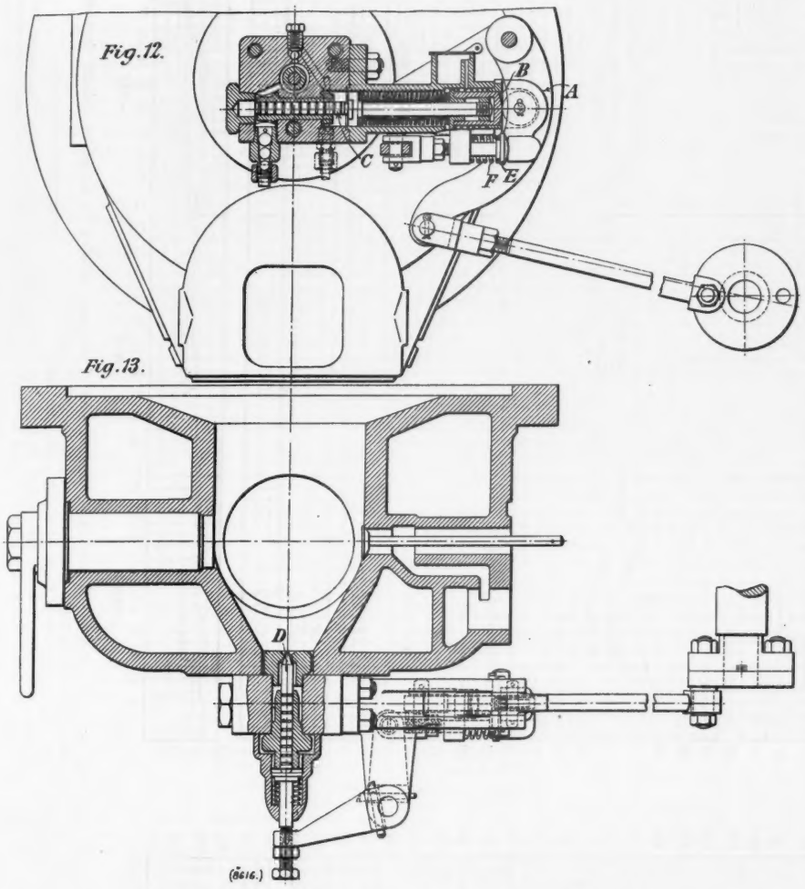


FIG. 11. HORIZONTAL CRUDE OIL ENGINE; MESSRS. FIELDING AND PLATT, LIMITED, GLOUCESTER.

The number of windmills exhibited at Leicester appeared to be about the same as usual. Most of these are arranged to work reciprocating pumps for farm and domestic water supply. Messrs. Telford, Grier and Mackay, Limited, of 2 to 10 Carrick-street, Glasgow, are, however, demonstrating the possibility of employing windmills for electric lighting purposes. The windmill is of the usual multivane type on either a light steel tower structure or a single steel pipe-mast supported by guys. The "Airolite wind turbine," as the machine is called, has a weatherproof dynamo at the top of the tower or mast, driven through gearing. The whole of the running parts work in ball or roller bearings. The "Airolite" plant is listed in eleven sizes, the smallest comprising a 9-ft. wheel geared to a dynamo rated at 300 watts, and ranging to a 50-ft. wheel driving a 21 kw. dynamo. The former is stated to develop 100 watts and 300 watts, respectively, in 10 m.p.h. and 20 m.p.h. breezes, while under similar conditions the latter will develop 6 kw. and 18 kw. A 9-ft. wheel complete with dynamo, and a 30-ft. tower is listed at 160*l*., the price for a 50-ft. wheel and dynamo on a 70-ft. tower being 1,000*l*. The necessary batteries are extra in each case. Assuming that the 50-ft. plant could be erected complete with batteries for 1,600*l*., and that in a favourable situation it would generate 24,000 kw.-h. per annum as stated, it is evident that even with a liberal allowance for interest and depreciation the cost of electricity would be far less than the average price paid by town consumers.

Very large displays of agricultural engines and machinery were made by Messrs. Marshall, Sons and Company, Limited, of Gainsborough, and by Messrs. Clayton and Shuttleworth, Limited, of Lincoln. Both firms showed portable steam engines of the familiar type. It may be noted with regret that the meaningless term, "nominal horse-power," is still retained for portable and traction engines by manufacturers. Steam road rollers are also shown by both the firms named, as well as crude oil engines, thrashing machinery, traction engines, &c. In the latest design of the Marshall road rollers, interchangeability of parts appears to have been pushed to the utmost limit, even the boilers being interchangeable one with another. All parts can therefore be replaced either from stock or from other machines, and put into service without any fitting whatever, a feature which will be much appreciated by those who have to maintain these vehicles on the roads. The engines are fitted with piston valves operated by radial valve gear. Each road wheel has its hub and spokes combined in a

EXHIBITS AT THE ROYAL SHOW AT LEICESTER.



FIGS. 12 AND 13. SPRING INJECTION GEAR FOR COLD-STARTING OIL ENGINE; MESSRS. BLACKSTONE & CO., LIMITED, STAMFORD.

substantial steel casting, so that the danger of broken or loose spokes is eliminated. The roller rims are renewable, and the interchangeability of the driving wheels allows of their positions being changed should scarifying cause one side to be subject to more wear than the other.

In the above account of the Show considerations of space have made it impossible to refer to a large number of exhibits. Some of these, including the cable-ploughing engine of Messrs. Blackstone and Company, Limited, and the new steam wagon of Messrs. John Fowler and Company (Leeds), Limited, we hope to deal with in subsequent issues. The extensive display of small petrol and oil engines for various purposes by Messrs. R. A. Lister and Company, Limited, of Dursley, Gloucestershire; Messrs. Petters, Limited, of Yeovil; the National Gas Engine Company, Limited, of Ashton-under-Lyne; Sir W. G. Armstrong, Whitworth and Company, Limited; Messrs. Ruston and Hornsby, Limited, of Lincoln, and other well-known firms, can only be given passing mention. Messrs. W. & T. Avery, Limited, of Birmingham, were at the show as usual with weighing machines, an advantageous feature of some of these being the position of the whole of the knife edge mechanism overhead, out of the way of water and dirt. Messrs. George Cradock and Company, Limited, of Wakefield, were also present with a large variety of steel ropes for practically all purposes.

ROYAL SOCIETY OF ARTS.—The Council have awarded the Society's silver medal to the authors of seven papers read at the ordinary meetings, to the authors of two read in the Indian Section, and to the authors of two read in the Dominions and Colonies Section.

INDUSTRIAL NOTES.

A CONFERENCE was held last week in London between representatives of the Engineering and Allied Employers' Federation, and of the Amalgamated Engineering Union and of other trade unions having members working in the engineering industry, with a view to discuss the unions' application for an all-round increase of £1 per week in the wages of all grades of workers. Sir Allan Smith occupied the chair, and reviewed the economic position of the industry, the rates of wages, cost of living, cost of transport and all other items such as rates and taxes which affect the cost of production. Mr. J. T. Brownlie, president of the Amalgamated Engineering Union, re-stated the men's case for the advance, adding that its grant by the employers would not make up the real cash value of the men's earnings to the pre-war level of wage values. It was decided to adjourn the joint conference until Wednesday, the 16th inst.

The twenty-fifth annual report now issued by the General Federation of Trade Unions states that the number of societies affiliated in 1922 was 126, with an aggregate membership of 1,371,634; in 1923, the figures were 125 and 1,056,131; and in 1924 they were 117 and 920,050. Receipts followed the falling-off in membership, and were, for 1924, 60,952*l.*, as against 71,020*l.* in 1923. In 1924 the reserve fund stood at 108,960*l.* The report states also that the tragedy of the unofficial strike as recently practised was the misery it unsympathetically inflicted upon other trade unionists. Some leaders of these strikes had spoken contemptuously of the general public. But 90 per cent. of the general public were workers, or the dependants of workers, and to the extent that these were inconvenienced and prejudiced the unofficial strike was anti-social. Sooner or later the public would realise the anti-social nature of the unofficial and so-called sympathetic strikes, and might then act as drastically towards the strikers as the strikers had acted against them, because they believed that such strikes held up the public services, inflicted hardship upon the community and if persisted in might become an effective way of promoting unemployment, of dissipating trade union and friendly society funds, and of bringing ruin upon industries without which the people could not live.

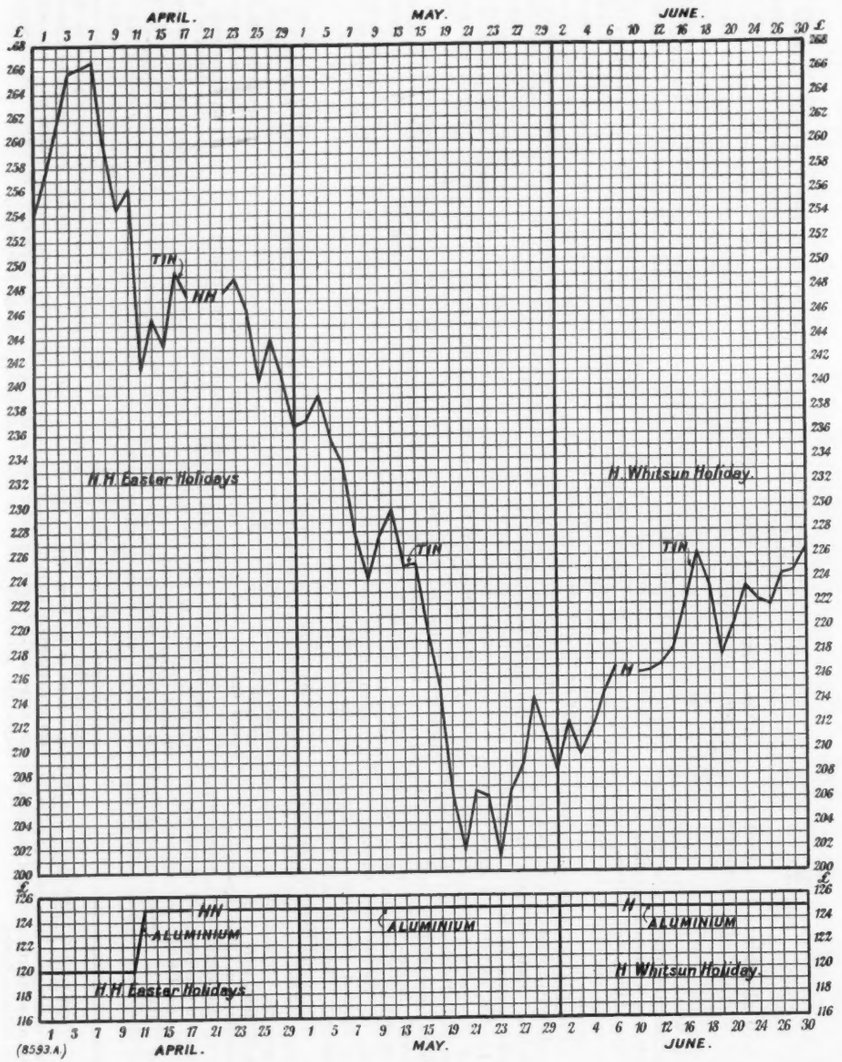
Since our last announcement, on page 24 *ante*, the situation in the building trades has become worse. The proposal prepared by the employers and submitted to the Minister of Labour read as follows: "Upon appointment of a Court of Inquiry, and in order to preserve a state of peace during the same, the employers will suspend their notices pending the report of such Court, provided that the operatives on strike at Liverpool and other places return to work immediately, and that the National Federation of Operatives suspend their other hostile actions against constitutional agreements pending the issue of such report." We may here remark that Mr. A. G. White, Secretary of the Employers' Federation, has denied that the unofficial strike at Liverpool was the sole reason for the national lock-out. The employers regarded the Liverpool strike only as a culminating instance of a long series of breaches of agreement. The employers' proposal which we give above was submitted to the men, who did not receive it favourably. The Court of Inquiry was appointed, and commenced sitting at the Law Courts on Friday last. It consists of Lord Buckmaster, Chairman; Mr. F. A. Hargreaves, Chairman of the Cotton Spinners' and Manufacturers' Association; and Mr. A. Pugh, General Secretary of the British Iron, Steel and Kindred Trades' Association. In the meantime the building operatives in large numbers went out on strike last Saturday.

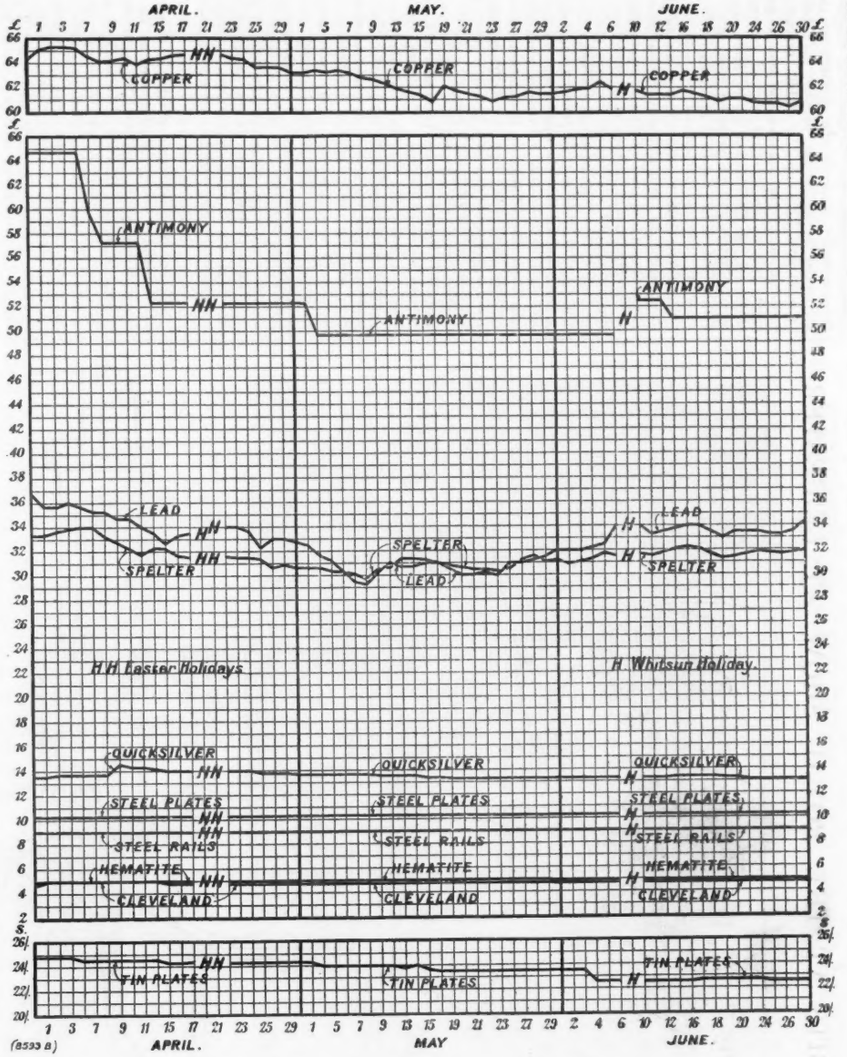
The annual conference of the National Union of Railwaymen is being held this week at York. In the course of his opening address, Mr. J. Marchbank, the retiring president, recalled the efforts of the railway companies to obtain modifications of the national agreements, and said the union successfully defended the main principles, adding that the decision to accept the findings of the National Wages Board, in view of all the circumstances, was a wise one. The National Union of Railwaymen was anxious to mitigate any hardship which the award of the Board might impose on certain locomotive men; this did not prevent their acceptance of it, subject to negotiation with the railway managers on the question of hardship and anomalies. The underlying reasons of the recent strike of locomotive men were early made apparent when the Associated Society of Locomotive Enginemen and Firemen offered to take N.U.R. members into immediate benefit, thus proving conclusively that they were more concerned in trying to alienate the loyalty of N.U.R. locomotive men than in dealing with the conditions of employment of their own members. The unfortunate spectacle then witnessed was the inevitable consequence of the divided counsels arising from the existence of sectional organisations. So long as sectional unions remained he was afraid that incident would not be the last of its kind. Experience had proved that the machinery of the Central and National Wages Board was sound. No sensible body of men wanted to strike every time a difference arose with their employers, and railwaymen were fortunate in having machinery which provided for a full and immediate examination in open court of the circumstances surrounding any dispute. The position in which the railway shopmen were placed at this moment was also due to the unfortunate division in their ranks; they were split into separate unions. It might be necessary later, Mr. Marchbank added, to make a definite stand against the reactionary methods of the craft unions in order to establish national standard conditions for the N.U.R. members in the railway shops.

The annual conference of the Miners' Federation of Great Britain is being held this week at Swansea, Mr. Herbert Smith, the president, occupying the chair. In his address at the opening meeting Mr. Smith said that the seven-hour day would not be given up, and the Federation had to proceed as opportunity presented itself to carry out the recommendation of the Sankey Commission for a six-hour day. The increase in the Federation membership during the last year was 38,660. Referring to the new agreement, Mr. Smith said it did not give all they desired, but it was the best possible agreement under the present circumstances. The mines for the nation was their policy, and the government of the industry by the miners and the people was the Federation's method. Mr. Smith stated that 1,192,300 men were employed in the coal industry, of which 788,520 were members of the Federation.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal Markets.)





NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for fine "foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. Middlesbrough prices are plotted for steel plates and rails, and also for hematite and Cleveland pig-iron. The prices given, in the case of steel plates and for ship, bridge and tank qualities, and those for steel rails are for heavy sections. The pig-iron prices are for East Coast hematite and Cleveland iron, both of No. 1 quality and for home consumption. The price of quicksilver is per bottle, the contents of which vary from 70 lb. to 80 lb. The price of tin-plates is per box of I.C. cokes f.o.b. at Welsh ports, but in other cases the prices are per ton. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each.

CALENDAR.—Messrs. Cochran & Co., Annan, Ltd., boiler manufacturers, Annan, Scotland, have issued a weekly tear-off Calendar, from the current month to June of next year.

MODERN TENDENCIES IN WATER-WHEEL DESIGN.*

By HJALMAR O. DAHL (Royal Institute of Technology, Stockholm).

SWEDEN is, for the most part, a country of small hills and dales, and the available sources of water power are as a rule, distinguished by low heads. Natural lake reservoirs are common, facilitating regulation. These conditions have influenced the design of the water turbines employed, in that it has been of importance to devise turbines with as high a speed as possible in order to reduce the cost of the electric generators used, and latterly have led to the construction of very large units with the object of gaining the greatest possible simplicity in design and operation.

The development of turbine engineering has for natural reasons been closely associated with the question of electric transmission of power by means of alternating current over long distances, introduced in the nineties. The runner of a turbine is defined by the specific speed n_s, which expresses the number of revolutions of a model turbine, developing exactly 1 h.p. at a head of 1 metre. For a turbine which under a head of H metres will develop N h.p. and runs at n revolutions per minute, we obtain the equation

$$n_s = \frac{n \sqrt{N}}{N \sqrt[4]{H}} \dagger$$

At the beginning of this century a specific speed of $n_s = 300$, or somewhat more had been obtained in America. The Finshyttan Company, in Sweden, succeeded, in 1905–06, in manufacturing fast-running Francis turbines with $n_s = 320$–350, and with a maximum efficiency of 85–87 per cent. for runners of about 1 m. outside diameter. The efficiency below full capacity was also relatively good.

Where the available head has permitted it, double turbines with a horizontal shaft have been preferred in Sweden, and even what are termed "quadruple turbines" have been installed, in order to increase the speed. Even where a vertical arrangement has for some reason or another been chosen, double turbines, and sometimes triple turbines, have been erected in order to obtain at the prevailing low falls a speed more suitable for direct coupling. In time the specific number of revolutions was gradually increased to about 400, whilst in the main the old type was adhered to.

The development in America followed different lines; the single-runner vertical turbine with spiral casing of concrete was quite generally adopted and became almost standard practice. As yet, it had not been possible to obtain a higher specific speed than about 400, a figure which for most cases is rather low and leads to a high cost for the generator, with a decrease in the efficiency, often to such a degree that the gain in the turbine is lost in the generator.

The Royal Board of Waterfalls (Kungliga Vattenfallsstyrelsen) which, in Sweden, attends to the development of State water power, had in its earlier installations at Trollhättan, Porjus and Alvkarleby given a strong stimulus towards the development of improved turbines, but this is especially true of the plant now under construction at Lilla Edet on the Göta älv below Trollhättan. The head at Lilla Edet normally varies between 5·6 and 6·8 m. with a normal average of 6·5 m. The first installation will use somewhat more than 400 cu. m. per second, while in the final stage of development about 900 cu. m. per second will be utilised.

The first investigations of the Board in connection with this station, in the year 1917, were concerned with a number of alternative solutions: vertical single rotor turbines of 5,400 or 3,300 h.p., vertical double turbines of 4,000 h.p., and horizontal quadruple turbines of 4,400 or 3,900 h.p. In each case only fast running Francis turbines were considered, with n_s from 330 up to 415. It was soon found that horizontal turbines had to be abandoned in this case, on account of the large space occupied by them and their large dimensions in proportion to the head and the variations in the water level. Of the vertical turbines, the single runner type offers greater simplicity, and probably a somewhat higher efficiency. The vertical double turbine gives a higher number of revolutions, and therefore permits of a cheaper generator, in addition to which, with the sacrifice of efficiency, higher water speeds can be employed and a greater power obtained in a smaller space, thus reducing building costs. Having regard to the situation at that time, the proposition considered a first installation of five double turbines of 6,600 h.p. at 6·5 m. head and 68·3 r.p.m., corresponding to n_s = 380, and then, as a first extension, the installation of four single turbines of 5,400 h.p. and 53·7 r.p.m. with the object of taking care of the minimum load of the station, with the best possible efficiency.

The end of the war, however, resulted in a rapidly diminishing demand for electric power, before the machinery had been ordered, and the Royal Board of Waterfalls then decided to continue its investigations.

With special regard to the electric equipment, and in consideration of the future operation, it was thought desirable to have fewer and larger units, and plans were accordingly prepared for vertical double turbines of 10,000 h.p. at 62·5 r.p.m. By this arrangement the total length of the power station could be considerably reduced, a circumstance which, for considerations of space, was of great importance.

After the specification for tenders on 10,000 h.p. double turbines had been distributed during the summer of 1921, a number of tenders were received for this type of turbine in respect of both double turbines and tandem turbines, but, in addition, no less than three firms were able, as an alternative, to offer single turbines of the same power and speed, and a couple of them even went so far as to propose the increase of the speed to 83·3 r.p.m. These values correspond to an $n_s = 600$ or 800 respectively. The problem of fast running turbines appears lately to have developed very rapidly.

The author made an interesting experiment at A. B. Finnshyttan as early as 1906 with a small fast running water turbine, and, with the relatively good efficiency of 75 per cent., attained a specific speed of 462. The turbine, however, through which the water passed, chiefly in an axial direction, and which had seven blades in the rotor, showed a comparatively rapid decrease in efficiency with a decreasing load. Professor Kaplan, of Brün, later succeeded, by shortening the blades and removing the outer band connecting these blades, in attaining values for n_s of 800 and more. These runners, which had almost the appearance of propellers, gave with a certain load a high efficiency, but also showed with an altered gate opening a great reduction of efficiency. Prof. Kaplan then hit upon an idea which at first appeared fantastic, but which in itself was good, *i.e.*, to design the runner blades so that they could be turned, whereby the efficiency could be maintained at a high value over a very large range of load. The number of blades was reduced to four or even to two.

It proved difficult to obtain the good results which Professor Kaplan had obtained with a straight and relatively long draft tube, when connecting the turbine to a curved suction tube. Professor Kaplan, however, continued his work and was successful in designing a suitable draft bend for the suction tube of the turbine, distinguished by a very much flattened and broadened discharge end, while the bend itself was very sharp, the outer contour even being sharply bent to an angle of 90 deg. The Board of Waterfalls opened direct communication with Professor Kaplan as early as 1919, but it soon became obvious that the size of the suction pipe which would be necessary for a single turbine of 10,000 h.p. would increase the costs so much that this solution of the problem could, for economic reasons, not be adopted. The Verkstaden in Kristinehamn had made trials with the Kaplan turbine in 1920-21, and this firm at the end of 1921 was in a position to offer the Board of Waterfalls a Kaplan turbine with a more suitable shape of suction pipe.

Another firm, which was able to offer an alternative tender for single runner turbines, was A. B. Finshyttan in conjunction with F. Neumeyer A.G., München. Their tender related to a rapid running turbine of Dr. Lawaczeck's design, with blades of very unusual shape. It would appear that the passage of water was intended to be decidedly in a centripetal direction; there was no outer band and each blade was constructed separately and fastened to a common hub by means of bolts, so that the large diameter of the rotor of 6 m. would not cause any particular difficulties. The runner had been subjected to certain preliminary tests but had not then found any practical employment.

Finally, Nydqvist and Holm A. B., of Trollhättan, together with Th. Bell and Co., of Kriens, Switzerland, had offered a fast running turbine which had been recently developed and tested by the latter firm in their own testing station. Concerning the constructive details of this turbine, no particular information was given. Both for the Bell and for the Kaplan turbine a speed of 83·3 r.p.m., corresponding to $n_s = 800$, was proposed, while for the Lawaczeck turbine a speed of 62·5 r.p.m., corresponding to $n_s = 600$, was proposed. Under these circumstances, the Board of Waterfalls decided in principle to go in for single runner turbines with $n_s = 600$, in spite of the difficulties. The Kaplan turbine was the one concerning which most experience had been obtained, and with this turbine the best efficiency curve at varying loads could be expected. It was, however, expensive and its suction pipe would always increase the cost. The Board of Waterfalls ordered its first Kaplan turbine of 10,000 h.p. and 62·5 r.p.m. at a head of 6·5 m., in the spring of 1922.

A further turbine had soon to be ordered, and the other designs offered, were, in respect of their greater simplicity and cheapness, of the greatest interest. Investigations showed that the Bell turbine had been tested with a very long suction bend, a design which would have been almost impossible to use at Lilla Edet; but it was just on this long suction bend that the good results largely depended. The type could, however, at the time, only be regarded as in a preliminary state.

Further investigations and tests led to the ordering, first, of one Lawaczeck turbine for the second instalment at Lilla Edet, and later, after careful comparison between the new tenders for both Kaplan and Lawaczeck turbines, to an order for an additional Lawaczeck turbine for the third enlargement, with which the first stage of development was complete.

The Lawaczeck wheel will have a diameter of 6 m. and will thus be the largest turbine runner hitherto made in the world. The diameter of the Kaplan turbine will be somewhat less, about 5·8 m. Owing to the fact that the Lawaczeck turbine has fixed blades, it gives an efficiency curve characterised by quite low values at a small load, efficiencies of 83, 87, 81, 73 and 65 per cent. being guaranteed at loads of 8/8, 7/8, 6/8, 5/8 and 4/8. This decrease is not of great importance, as it is estimated that these turbines will always be run at approximately the most advantageous loads. For the sake of comparison, it should be mentioned that the Kaplan turbine at corresponding loads is guaranteed to have efficiencies of 84, 87, 88, 87 and 86 per cent. respectively, and thus offers great possibilities for taking up variations of load without wasting water. In addition, the Kaplan turbine is calculated to be capable of an overload up to 11,200 h.p. without any great reduction of efficiency.

It is thus on the direct initiative of the Board of Waterfalls that the Lawaczeck turbine has been rapidly brought through the experimental stage to an efficient design, and the Board has thereby given a particularly powerful impulse to the development of turbine practice in Sweden and, indirectly, abroad. This work will be useful to the Board for its future installations and also for other electric works, the large turbines at Lilla Edet representing, so to speak, a pioneer step, involving a certain amount of risk in spite of the extensive preliminary tests. The author considers that these risks lie principally in the danger of cavitation phenomena occurring in the blades, wherefrom corrosion might result, and a certain reduction in efficiency and output. In spite of the fact that the Lawaczeck turbine has so far found little practical employment, these risks appear to be less in the case of this turbine than they are in the Kaplan turbine, with the suction heights here in question.

* Paper, abridged, contributed to Section B of the World Power Conference on July 4, 1924.

† In the British system of units the unit is one English foot, for which reason n_s metric = 4·44 n_s British.

STEAM TURBINES.*

By the HON. SIR CHARLES A. PARSONS.

IT is now well understood that in steam turbine installations, where steam economy is of prime importance, pressure compounding, or the placing of many simple turbines in series on the steam flow, is essential; further, that one of the fundamental requisites for the attainment of high steam economy is the operation of the turbine at an appropriate overall velocity ratio, or ratio of mean blade velocity to steam jet velocity.

It is known from the laws of thermo-dynamics that the thermal efficiency of a heat engine depends chiefly upon the temperature range; that, in accordance with Carnot's principle, the temperatures at which heat is supplied and withdrawn should be as widely separate as possible. A large temperature range must necessarily be accompanied by a large pressure range. This is exemplified in the case of steam by the fact that the latent heat, which is a large proportion of the total heat, is absorbed during the process of evaporation, and in order that this may take place at a high temperature, the boiler pressure must be high. Accordingly, the expansion ratio in modern steam turbine practice is being increased, and in turbines under construction is in the neighbourhood of 1,500 to 1. The corresponding temperature range is from about 470 deg. saturation temperature, raised to 750 deg. Fahr. by superheating, down to about 75 deg. Fahr., or a maximum drop of about 675 degs.

In modern turbine design there arises the fundamental question of high steam velocities *versus* moderate or low steam velocities. From the point of view of reduction of the number of stages, and therefore the overall length of the turbine for a given capacity, it is clear that high steam velocities are all to the good, but in proportion as the steam velocity is increased, the essential benefit of pressure compounding is sacrificed,

* Paper, abridged, contributed to Section D of the World Power Conference on July 4, 1924.

for the advantage of that principle does not rest solely on the fact that the hydraulic head under which each simple turbine of the series works, is reduced, but also on the evidence that the efficiency of conversion of the available energy of the steam into mechanical work in the nozzles and blading, increases as the velocity is decreased.

It will be recalled that de Laval's simple turbine, which to many would have seemed to offer the best solution of the economic utilisation of the enormous available energy in high pressure steam, fell short of anticipated results owing to the heavy nozzle losses which occur when very high expansion ratios are dealt with in a single drop.

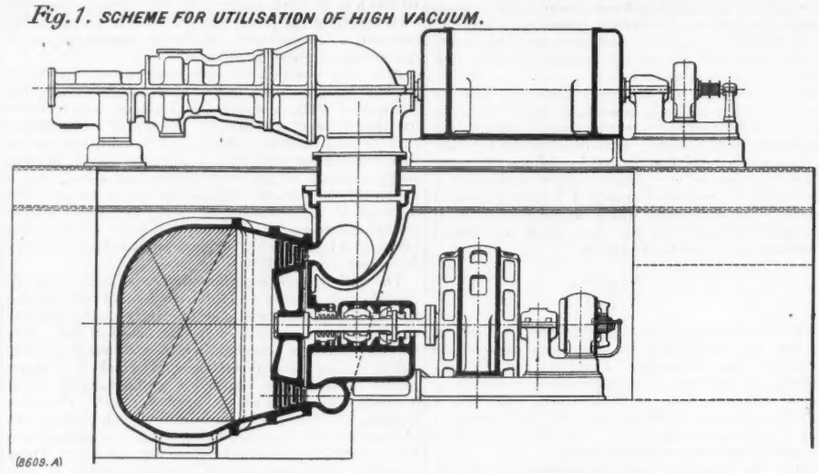
The high economy shown by the published test results of the Ljungström radial flow double rotation turbine which operates with higher steam velocities than are usual in parallel flow practice, has been attributed by some mainly to the reduction of steam leakage at the glands and dummies by means of a multiplicity of very fine labyrinth packings. Recent researches in the laboratory, with fixed nozzles, but without blade rings, have confirmed the view that nozzle efficiency diminishes with increasing steam velocity, and it remains to find out the causes of this loss of efficiency and whether it may be possible to reduce or eliminate it.

Apart from the effect of jet velocity upon nozzle efficiency, there is also the fact that the stage efficiency of a steam turbine is lower with saturated steam than with superheated steam. Laboratory tests have proved that the weight of steam discharged by a nozzle using steam initially dry-saturated is appreciably greater than that which theory would indicate, and it is thought by some that the cause of decreased efficiency of stages using saturated steam is closely connected with this phenomenon. It is thought, in fact, that the steam, during expansion, becomes super-saturated, and does not give up so much of its latent heat as it would do under conditions of thermal equilibrium, with the result that the available heat for a given ratio of expansion is considerably less than that indicated by calculation on the basis of thermal equilibrium. This question is closely bound up with the thermodynamics of steam turbine design. All engineers engaged in such work are desirous of reducing the nozzle and blading calculations to as nearly an exact science as possible, and of placing test results of different turbines under different steam conditions upon a rational basis of comparison. Up to the present, although a good approximation has been attained, this problem cannot be said to have been completely solved, the influence of cumulative heat arising from expansion of the steam with a stage efficiency less than unity, and the above-mentioned fact of decreased stage efficiency in regions where wet steam is found having much complicated the problem. With regard to the design of blading of the impulse type, there are two schools of thought. One of these favours the proportioning of the passages so as to obtain as far as possible what is known as "free diviation"—in which the blades are arranged so as simply to deflect the steam jets issuing from the nozzles, without alteration to the steam pressure. The other favours the employment of a certain amount of pressure drop in the revolving blade passages. The latter procedure is conducive to higher stage efficiency, but involves some leakage radially over the shrouding, and also circumferentially in the case of partial admission; in such cases the same principle is used as has for many years been standard in the case of reaction turbines, namely the adoption of large radial clearances, but reduced axial shroud clearances.

The question has arisen as to whether a compromise between the so-called "Impulse" and the so-called "Reaction" principle can be made to give a higher efficiency than either principle alone, and it is interesting to note that Impulse turbine builders and Reaction turbine builders are approaching this question from opposite standpoints. At the present time Reaction turbines are generally built with equal expansion ratio in the moving and guide rings of a reaction pair. Experiments have been made with a different division of the pressure drop, but up to the present, equal pressure drop in the fixed and moving blading and similar construction for these parts have given the best all-round result.

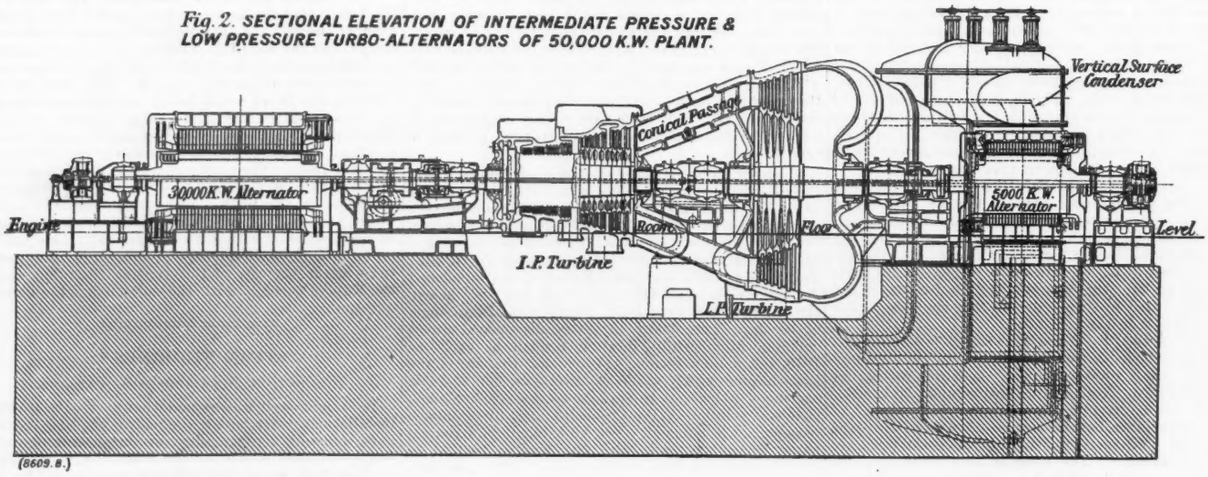
Advance in the direction of increasing the thermodynamic value of the heat in the steam without unduly increasing the maximum temperature, is being made by increasing the mean temperature of heat reception. One method of effecting this, is the adoption of regenerative feed water heating, by using steam tapped off from successive stages of the turbine. The necessity to heat the feed water, that is, to reheat the water of condensation, is the defect of the Clausius' cycle. If however, a perfectly regenerative process could be employed for heating the feed, the efficiency of the Clausius' cycle for saturated steam would be brought up to that of the Carnot cycle. In such a process the steam tapped off has been expanded, doing work in the turbine, down to the temperature at which it is required to heat the feed water. Since a certain amount of heat is required for this purpose in any case, the work obtained from the tapped off steam is obtained merely at the expense of additional heat equal to the work done or in other words at 100 per cent. efficiency. Expressed in another way the utilisation of some of the

Fig. 1. SCHEME FOR UTILISATION OF HIGH VACUUM.



(8609. A)

Fig. 2. SECTIONAL ELEVATION OF INTERMEDIATE PRESSURE & LOW PRESSURE TURBO-ALTERNATORS OF 50,000 K.W. PLANT.



(8609. B.)

TABLE SHOWING THE OVERALL THERMAL EFFICIENCIES WHICH IT IS ESTIMATED COULD BE REALISED WITH INCREASED BOILER PRESSURES, UP TO 2,000 LB. PER SQUARE INCH.

(Based on the Callendar Tables and Formulae for the properties of steam.)

Column No.	1	2	3	4	5	6	7	8	9	10	11	12
Case No.	S.V.P. lbs. gauge.	S.V.T. ° F.	° F. initial superheat.	Assumed reheat pressure lbs. abs.	Reheat temp. ° F.	Restored superheat ° F.	Exhaust vacuum ins. Hg. Bar. 30·0"	Stage feed water heating from 65° F. up to (° F.)	Thermal efficiency (from steam to electricity)	Assumed boiler plant efficiency (including all aux.).	Overall Thermal efficiency (from coal to electricity).	Per cent. gain.
I.	250	750°	344°	65	700°	402°	29·25"	360°	31·6	84·0	26·52	—
II.	500	750°	281°	100	700°	372°	29·25"	420°	33·5	83·5	27·97	5·45
III.	1,000	750°	204°	150	700°	343°	29·25"	510°	35·2	83·0	29·20	10·08
IV.	1,500	750°	153°	250	700°	299°	29·25"	550°	36·6	82·5	30·20	13·82
V.	2,000	750°	114°	400	700°	254·5°	29·25"	600°	37·5	82·0	30·75	15·90

NOTES:—

1. S.V.P. = Stop valve pressure.
2. S.V.T. = Stop valve temperature.
3. Feed water heated to within about 50 deg. F. of boiler temperature by means of steam withdrawn from turbine blading at several points.
4. Boilers equipped with economisers or air pre-heaters or both, so as to recover heat from the flue gases and maintain high thermal efficiency.
5. Dynamo efficiency taken as 96·5 per cent. at full rated output.

heat of the steam to heat the feed water reduces the amount of heat that is lost by condensation in the condenser.

A slight practical objection to such a system of feed water heating is the additional complication of the pipework involved, if a sufficient number of feed water heaters in cascade are employed to approximate to a thermo-dynamically reversible process; but even with two or three stages, very considerable heat economy can be effected. As a compromise, feed water heating by steam extraction from a few stages of the turbine, in conjunction with economisers, is generally accepted practice in modern power stations, but there is a tendency to develop this system further so as to attain higher feed water temperature by the steam heating. It then becomes necessary, as an alternative or partial alternative to the economiser, to adopt some other means of absorbing the residual heat of the flue gases, such as a regenerative preheating of the air for the furnaces. Feed heating in a single stage by partly expanded steam is a well-known procedure; it was proposed by James Weir in 1876, by Normand in 1889, and in progressive stages by Ferranti in 1906; with marine turbines, it is general practice to utilise the exhaust steam from the auxiliary engines, at a pressure slightly above atmospheric for this purpose. Similar use can be made in power stations of any low grade heat that is available, such as in steam from turbine glands, ejector air pumps, &c.

Fig. 4. ARRANGEMENT OF 50,000 K.W. TURBO ALTERNATOR & SURFACE CONDENSERS, SHOWN IN PLAN.

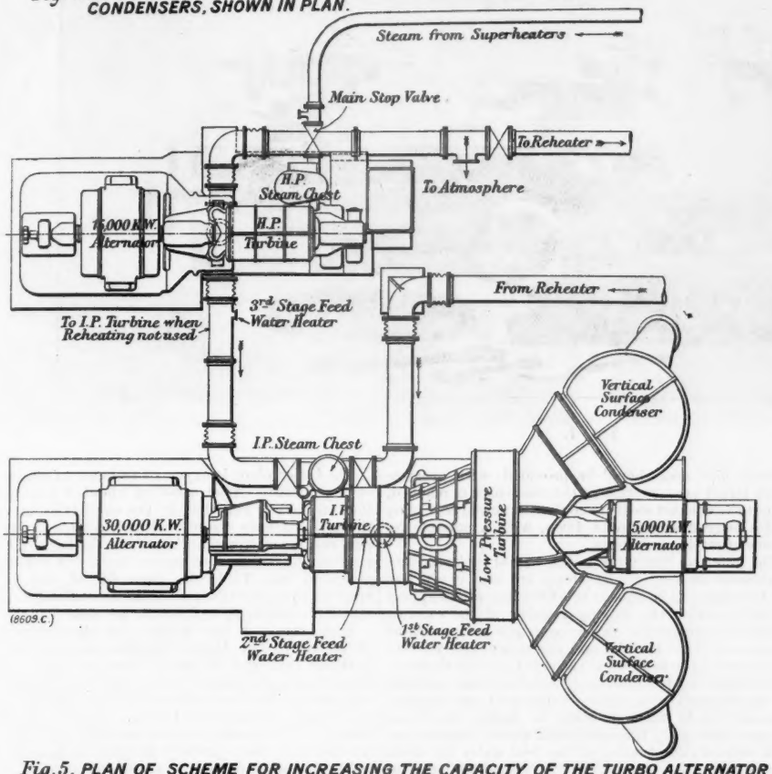
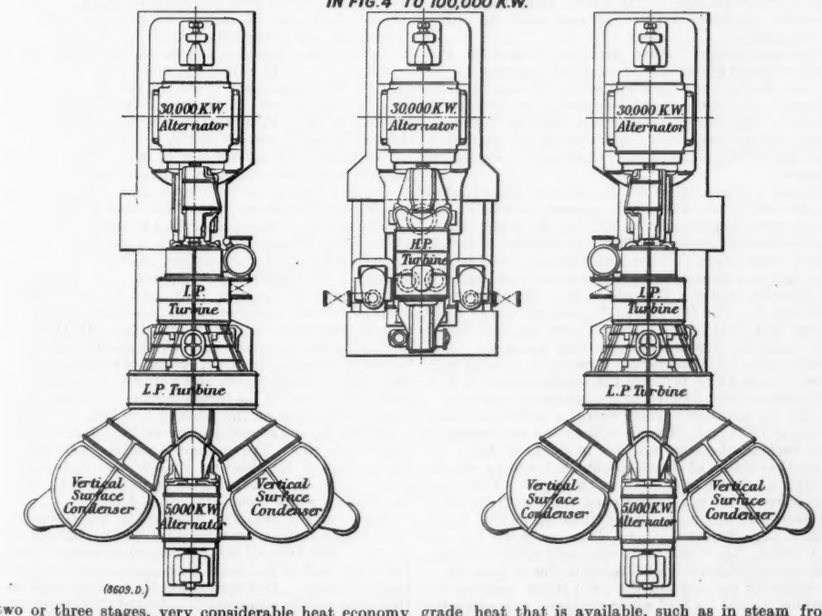


Fig. 5. PLAN OF SCHEME FOR INCREASING THE CAPACITY OF THE TURBO ALTERNATOR IN FIG. 4 TO 100,000 K.W.



As a second method of increasing the mean temperature of heat reception, an advance might be made if after superheating to the maximum temperature further heat were added so as to maintain isothermal expansion throughout the initial stages of the turbine. This could only profitably be carried to such a point that subsequent adiabatic expansion in the turbine to the condenser vacuum would leave the steam just saturated. Such a method (of preliminary isothermal expansion) was proposed many years ago, but the mechanical difficulties in the way to its complete realisation would appear insurmountable. An approximate solution, however, is being worked out at the present time; in some installations the steam, after a certain amount of expansion in the turbine, is extracted and raised again to a high temperature in a reheater before re-entering the turbine. Reheating has also the additional advantage of extending the range within which superheat exists and of diminishing the range where moisture and consequent loss by water resistance or increased viscosity exists. This process might, of course, be extended to include reheat at various stages of the expansion. With a single reheat a compromise must be accepted when selecting the stage at which the steam is taken from the turbine. If reheating is carried out too soon then the heat added—although at a high mean temperature—is only of small amount. On the other hand, if reheating is carried out too late, then the heat added—although of greater amount — is received at a lower mean temperature, so that the mean temperature of reception of the cycle is not much improved.

If a curve be drawn showing the estimated percentage gain in thermal efficiency on a base of the proportion of expansion carried out before reheating, it is found that there is a fairly definite peak indicating the most appropriate reheating point. The maximum estimated gain in the case of a single reheat to the initial temperature of 750 deg. F. is about 7 per cent.

Since reheating the steam increases the total available heat per lb., more blading is required in the turbine to maintain the same average velocity ratio; this and other considerations tend towards the desirability of carrying out the expansion in two or more separate cylinders, the exhaust steam from any one cylinder being reheated before entering the next. Where such reheating is adopted special means must be provided to prevent over speeding of the machine owing to the large volume of steam stored up in the reheater and connecting pipes.

A third method of attacking the same problem is to increase the mean temperature of the heat reception by increasing the boiler pressure. With a boiler pressure of 250 lb. per square inch, a final temperature of 750 deg. F. after superheating, and a feed-water temperature of 79 deg. F., the mean temperature of heat reception is about 360 deg. F. But if the boiler pressure is increased to, say, 2,000 lb. per square inch, still superheating to 750 deg. F., then since the latent heat is received at the increased temperature of the boiler, the mean temperature is considerably increased, namely to 480 deg. F. If, in addition, we assume the water is fed into the boiler at the boiling temperature by means of feed heaters in cascade in each case instead of at 79 deg. F. the mean temperatures of heat reception are increased in the one case to 430 deg. F. and in the other to 680 deg. F.

Whilst such a pressure as 2,000 lb. per square inch has not been actually adopted in any commercial plant, there seems to be no reason why it should not be practicable in a large steam turbine installation. In such a case there may be a small auxiliary high-pressure turbine, having several stages of small diameter, running at high revolutions, and after dealing with the first few expansions, exhausting into the turbines working at ordinary pressures. Such high-pressure turbines are actually being built—one in this country for a pressure of 1,500 lb. per square inch, and one in the United States of America for 1,250 lb. per square inch.

With regard to the lower end of the temperature range the temperature of the cooling water here imposes the limit. An exhaust vacuum equivalent to 29·25 in. of mercury (barometer 30 in.) can be realised under favourable circumstances. This, however, involves the necessity of providing ample blade area and passage way for the great volume of low-pressure steam.

Throughout the stages of a turbine, the criterion of efficiency is the velocity ratio, and the areas of the blade passages successively increase in such proportions as to provide the proper ratio between the blade velocity and the steam velocity. The axial component of the steam velocity is carried on from stage to stage without appreciable loss. It is even built up to higher values as the peripheral and steam velocities increase. Its final loss at the exhaust end of the turbine, however, is practically unavoidable, and with the high peripheral speeds adopted in most low-pressure blading at the present day, an exhaust blade area which gives a perfectly satisfactory velocity ratio may entail a loss of energy in the issuing steam of considerable amount. Such loss is augmented if, for the sake of weight or cost, any sacrifice is made of the best velocity ratios, which sacrifice might otherwise be a perfectly justifiable compromise. It is evident, therefore, that the exhaust end of a turbine requires separate treatment in its design from the point of view of limitation of the leaving loss, that is, the energy lost in the issuing steam.

Broadly speaking, where high efficiency is the aim,

3½-IN. CENTRE, BACK-GEARED, SELF-ACTING LATHE.

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(For Description, see opposite page.)

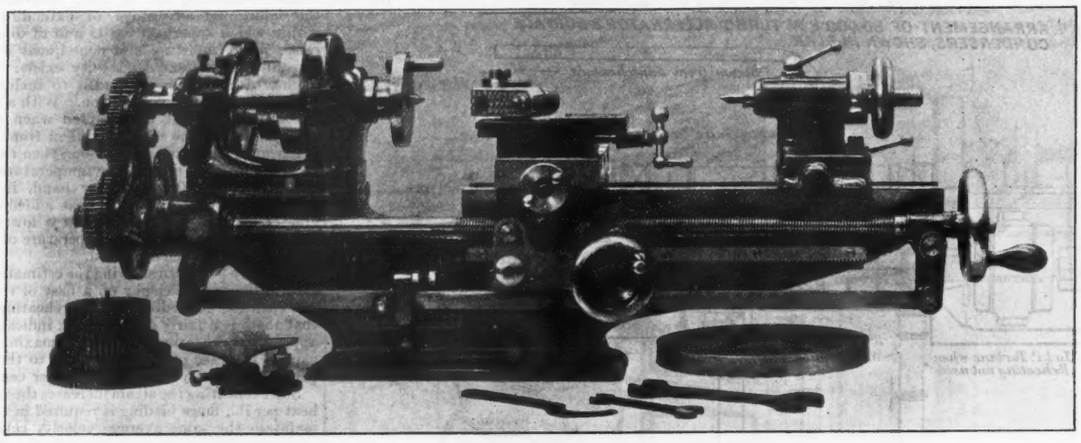

FIG. 1.

this consideration imposes a limit upon the axial velocity of the steam in the final annulus. For a given vacuum, therefore, the area of the final annulus must increase in proportion to the output, and for a given output any increase in the vacuum involves an increase in the area of the final annulus. It will be seen, therefore, that any effort to extend the steam cycle by lowering the temperature of condensation, brings at once into prominence the problem of the exhaust end.

Various expedients have been adopted for the purpose of surmounting this limitation. One method, commonly employed in both land and marine turbines, is to carry out the final stages of the expansion by divided flow, as, for example, in a double-ended low-pressure turbine, the steam entering at the middle and flowing in each direction towards an exhaust at each end.

In such an arrangement two exhaust pipes are provided and frequently two condensers. In another example of divided flow, some makers double only the last row or last few rows of blading, employing specially shaped passages to conduct the steam to the divided portion from the preceding stages.

The design of exhaust end advocated by Baumann is another attempt to overcome the same difficulty. In this device, instead of carrying over a part of the steam by special ports to additional blade rings, it is made to flow through inner annuli of the preceding blade rings, the vanes of these inner annuli being specially shaped to reduce the resistance involved to a minimum.

The area of the final annulus can be increased by increasing the blade height, and any means of extending the height permissible on a given diameter, is valuable for this purpose. Thus in many turbines the blades of the last stages are made of varying section and discharge angle, permitting a greater length ratio without unduly increasing the stress.

If no limit is imposed upon the diameter of the exhaust end or upon the revolutions, the simplest and probably best solution of the exhaust area problem in large machines, is to provide a separate low speed turbine of large diameter for the final stages of the expansion, having blades of normal profile throughout, and correspondingly high efficiency. This low speed turbine can be arranged in close proximity to the condenser, as illustrated diagrammatically in Fig. 1, page 64, so as to reduce to a minimum both the length and the resistance of the exhaust passages.

In the exhaust passage itself, it is not sufficient to provide area to reduce the mean velocity of the steam passing through it to a moderate value, but the exhaust steam must be distributed into the passage uniformly, so that the velocity is everywhere nearly the same. Neglect of this requirement leads to unnecessary hydraulic losses, and may also cause troublesome blade vibration in the final stages.

Many attempts have been made to obtain the benefit of the diffuser principle, which has been so commonly adopted in the case of water turbines, but in the case of steam turbines without substantial success. In any attempt to carry this principle into effect, ample exhaust pipe area should be provided, with progressively larger cross section as the condenser is reached, so that the exhaust steam from the last row of revolving blades is gradually slowed down, with a possible recovery of static pressure.

The practical difficulties in the way of such recovery of pressure in the exhaust steam are very great, and the best that can be done in this direction would appear to be to utilise the leaving velocity of the exhaust steam to overcome the resistance to flow in the exhaust passages, so that the absolute pressure at entry to the condenser is the same as at the exit from the blading.

Summarising the foregoing, there are four methods of improving the thermal efficiency of the thermodynamic cycle without going to higher maximum temperature:—(1) Increased feed water temperature, with regenerative heating of the feed water by steam drawn from the turbine. (2) Increased boiler pressure. (3) Re-heating of the steam after partial expansion. (4) Increased vacuum and means to utilise it effectively.

An application of these principles is made in the turbine plant of 50,000 kw., normal capacity to be erected in the new Crawford Avenue Power Station, Chicago, and now nearing completion at Newcastle-on-Tyne. In this plant there are three cylinders in series on the steam flow, each driving an alternator, the three alternators being electrically coupled in parallel.

Steam is generated at 600 lb. pressure and supplied to the stop valve of the high pressure turbine at 550 lb. pressure, superheated to 750 deg. F. After expansion in the high pressure turbine to a pressure of 100 lb. above atmosphere, it is led back through a well lagged pipe into a re-heater in the boiler house from which it is returned to the I.P. turbine at a temperature of 700 deg. F. The H.P. and I.P. turbines run at 1,800 r.p.m. and drive alternators of 15,000 kw. and 30,000 kw. capacity respectively. Further expansion takes place in the I.P. turbine to a pressure of about 2·0 lb. absolute, at which pressure the steam enters the L.P. cylinder, to be expanded to the condenser vacuum.

The low-pressure turbine drives a 5,000 kw. alternator at 720 r.p.m. Owing to the lower revolutions of this turbine, the area provided in the final stage is so large that blades of normal profile, but set at a slightly greater discharge angle, can be employed. The steam is condensed in twin surface condensers with the tubes vertical and having a total surface of 56,000 sq. ft. Fig. 2, page 64, is a sectional elevation of the I.P. and L.P. units. The whole installation of turbines, alternators and condensers is illustrated in Fig. 4, page 65.

About 22 per cent. of the total steam entering the turbine is used for feed water heating; it is extracted from the turbines at three points, the feed water being heated up from 65 deg. F. to 315 deg. F. in three stages before entering the economisers. A heat consumption of 10,265 B.Th.U. per kw.-hour is anticipated, or a thermal efficiency (from steam to electricity) of 33·2 per cent.

For recovery of the heat in the flue gases, economisers are used for a final stage of feed-water heating, and air preheaters, a regenerative process being employed in the latter to heat up the incoming furnace air.

The boiler plant is expected to have an efficiency of 86·5 per cent. After allowing about 3 per cent. for the total power absorbed by the auxiliaries, an overall thermal efficiency (from coal to electricity) of 27·80 per cent. is anticipated. This is on the basis of a boiler pressure of 600 lb. per square inch. A schedule is given in the Table on page 64 of the thermal efficiencies it is estimated could be realised with high boiler pressures, up to 2,000 lb. per square inch.

Some details of the turbines and alternators will be of interest. The three cylinders contain 64 simple turbines arranged in series, the first having blades 2½ in. long and ⅝ in. wide on a mean diameter of 30½ in. and the last having blades 40 in. long and 3⅜ in. wide on a mean diameter of 160 in. In view of the low density of the steam, the passages from the I.P. turbine onward have been specially designed to have the minimum of resistance and to avoid any sudden enlargements which would produce eddies or shock. The I.P. turbine discharges its steam directly into the L.P. turbine through a conical annular space surrounding the intermediate bearings, and the energy of the leaving velocity of the I.P. exhaust is thus conserved. (See Fig. 2). The maximum blade tip velocity is reached at the last ring of the I.P. turbine, where it is 760 ft. per second; in the L.P. turbine, which runs at 720 r.p.m., the maximum tip speed is 626 ft. per second.

The blades throughout are of mild steel, formed integral with their roots by rolling. They are fitted in serrated grooves in both rotor and cylinder, being inserted and driven up tight. The blades of the H.P. turbine and of the first half of the I.P. turbine are fitted with "end-tightened" shrouding made of manganese copper and brazed over tenons on the ends of the blades. "End-tightened" blading was introduced commercially in the year 1912, and has been widely adopted in land turbines of the reaction type and in several mercantile marine installations. In this type of blading the necessary running clearances are maintained in an axial direction, instead of radially, so that they can be made small, and adjusted and regulated under the control of the thrust bearing. The minimum radial clearances of the blading are thus no longer controlled by the necessity of minimising steam leakage over blade tips. The minimum radial clearances of the portion of the blading that is end tightened is ¼ in., whilst the radial clearances in the remainder of the blading range from ⅛ in. up to ¼ in.

Each turbine shaft is fitted with an emergency governor, and these are interconnected so that any one of them will trip all steam admission valves simultaneously and at the same time open a large vacuum breaking valve. In order to meet the special conditions that arise when reheating is adopted, the governing of the turbine has been arranged so as to avoid any danger of over-speeding due to stored steam. This is done by the provision of an independent governor valve on the inlet to the I.P. turbine, which receives steam from the reheater. The governor controlling this valve is set to operate at a speed about 2 per cent. in excess of that of the main governor, and with this lag will control the rate of steam admission to the I.P. turbine whenever the load on the plant is suddenly reduced. In case this valve should close for any

3½-IN. CENTRE, BACK-GEARED, SELF-ACTING LATHE.

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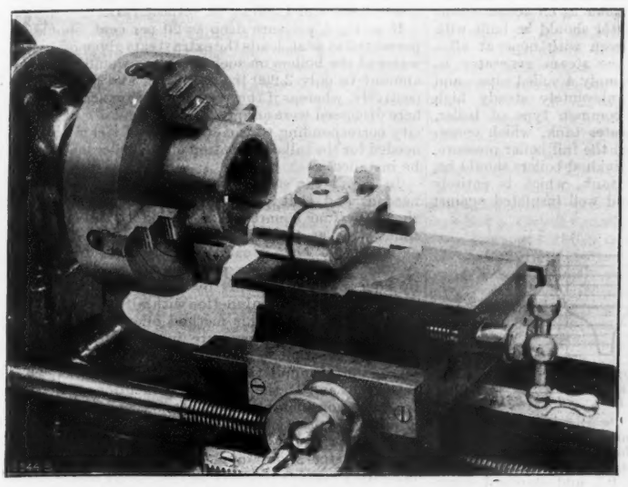


FIG. 2. TOOL HOLDER FIXED FOR BORING.

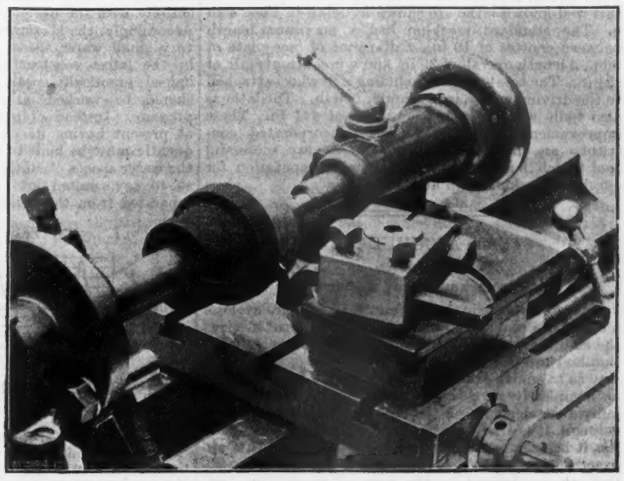


FIG. 3. TOOL HOLDER FIXED FOR PLAIN TURNING.

Fig. 4.

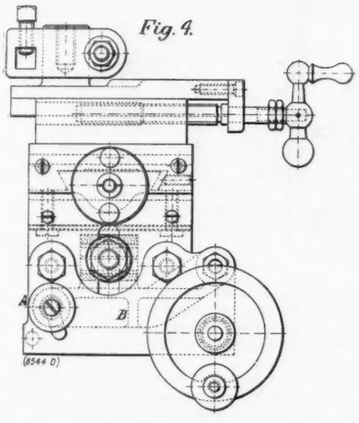


Fig. 5.

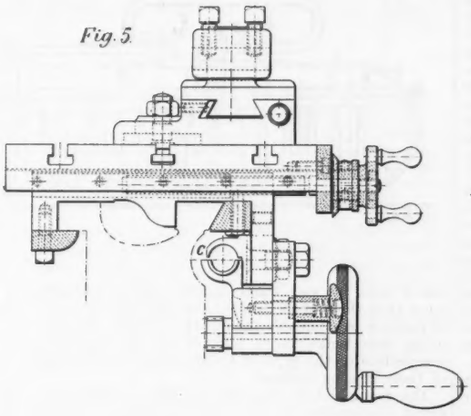
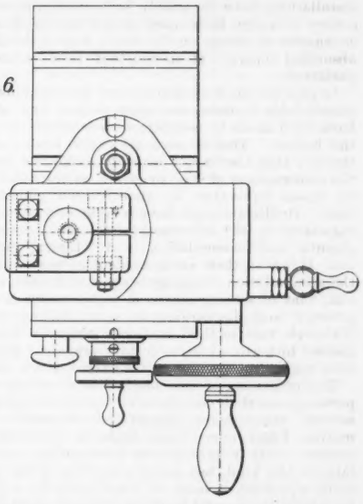


Fig. 6.



reason, whilst the main H.P. inlet remained open, a relief valve of ample area is provided on the exhaust pipe of the H.P. turbine and set to open at 130 lb. per sq. in. above atmosphere, whilst an increase in pressure of 140 lb. will operate an additional tripping device and shut off the main steam supply.

The alternators are wound for a three-phase supply at 13,000 volts, and embody the latest British practice. No main field regulators are used in their operation, the regulation being carried out by means of well designed exciter field rheostats. The ventilation is effected by means of the closed circuit system employing surface air coolers and separately driven fans, which have a much higher efficiency than high speed fans integral with the rotor shaft. The stator frames are being built in one piece, and the alternators are to be shipped completely wound.

Since, when starting up the plant, where will be insufficient steam to drive the L.P. turbine, the alternator coupled to this turbine will be run up as a synchronous induction motor. The three alternators will then be synchronised together and operated as one unit, giving a combined normal output of 50,000 kw.

The Crawford Avenue Power Station has been laid out for a total capacity of 500,000 kw. Fig. 5, page 65, shows how readily such an installation as the one described can be developed into one of 100,000 kw. without increase of the largest component units by replacing the H.P. unit by one of double the steam capacity, and by duplicating I.P. and L.P. units. There would thus be three alternators of 30,000 kw. output identical in design, and two small alternators of 5,000 kw. driven by the low-pressure turbines.

3½-IN. CENTRE, BACK-GEARED, SELF-ACTING LATHE.

Several improved features have been incorporated in the new model of their 3½-in. centre lathe by Messrs. Drummond Brothers, Limited, of Guildford. Two important modifications which have been made will be clear from Fig. 1. Firstly, the older method of utilising the lead screw for the hand traverse of the saddle by means of the hand wheel at the end of the bed has been superseded by a rack and pinion motion. By the use of a half-nut the lead screw may be disengaged and quick sliding performed by means of the hand wheel and cut steel pinion operated on the steel rack, which extends along the bed underneath the lead screw. The half-nut is dropped out of engagement by means of the small knob shown to the left of the apron front, and the hand wheel is seen to the right. The automatic throw-out for the lead-screw clutch is retained as in previous models, the adjustable stop, however, now butting against a small pad on the apron itself. This improvement is to be welcomed as a contribution to handier adjustment

Secondly, both a new top slide and tool holder have been designed, the former to accommodate the latter in a distinctly novel manner. The tool holder, Norman's patent, is unique, and assures against the dangers of incorrect setting unduly stressing the top slide, always a possibility with the older single clamp bolt with tool block and double set screws, and, for small lathes, cumbersome 4-bolt and double clamp plate method. Figs. 2 and 3 clearly show the arrangement. The new tool holder is clamped to a cylindrical pillar formed integral with the top slide, and is made of a hardened and tempered steel block, cut from the solid, with a central hole a sliding fit on the top slide pillar. The block is split to permit of clamping to the pillar by means of a hardened clamping bolt. The tool itself is carried in a square hole through the tool holder and is held by two hardened set screws. The construction has many advantages. In the older machines height adjustment of the tool was attained by packing; the American method is to use an arc-shaped packing wedge, which, however, alters the cutting angle of the tool with each adjustment for height. Odd length tools can be used. Only normal cutting stresses are carried on the top slide, which has additional metal in the right place. It will be seen from the figures that turning and boring with the same tool, if desired, are possible. Height adjustment relative to the lathe centres up to ⅜ in. is permitted, the tool meantime remaining firmly clamped in the square hole. This is effected by a single movement of the spanner on the clamping bolt, which locks the holder in any desired position. The cutting rake and clearance of the tool remain constant for all height settings, since the tool is shifted bodily. The angle made by the latter with the sides of the job also remains constant. A complete range of tool holder movement around the pillar is possible, thus permitting ready use of the boring bar. Fig. 3 shows the lathe set for plain turning a casting carried on the mandrel between centres, and a swan-neck roughing tool is shown in use. Simplification of work due to height adjustment will be apparent where worn or straight stem tools are concerned. For side cutting, facing, or taper turning, the correct

position is easily attained, the single clamp gripping the holder firmly immediately, while tools of different sections can conveniently be arranged to have their cutting edges at a desired height. Fig. 2 shows the tool holder set for boring, the advantage of wide range of position available for tool setting being again apparent.

These new features which have been incorporated in this well-known lathe are shown in detail in Figs. 4 to 6. The standard machine has a maximum length between centres of 16 in., a diameter of face plate of 9 in., a length overall of 39 in. and a breadth overall of 22½ in. The total weight, including a flywheel attached to the driving motor, is just under 600 lb. The lathe is also built with an extra long bed of 44½ in. These improvements which have been incorporated constitute an important advance in a very successful tool which has built up a valuable reputation for excellent workmanship and good service.

STEAM ACCUMULATION.*

By J. Ruths, D.Sc., Director of the Aktiebolaget Vaporackumulator, Stockholm.

The efforts made in the last few decades in the development of the economical use of energy have had in view the co-ordination of the various plants for the generation and use of mechanical and heat energy, in such a way as to enable excess and waste energy to be utilised as completely as possible. The construction of the individual elements of those plants has been carried through, it is true, in excellent manner, but nevertheless it has comparatively seldom been the case that an exact investigation has been made of the influence that the variations in the rate of production and consumption of heat and mechanical energy exercise on the working methods and the overall efficiency obtained. On the contrary, the heat balances of such installations have invariably been set down as if the source of energy to be used on the one hand, and the consumers of energy on the other, were delivering and absorbing energy at a constant rate without any variations.

In practice those variations have been accepted as an unavoidable concomitant phenomenon, and attempts have been made to counteract their effects by forcing the boilers. This causes considerable losses, owing to the fact that the supply of heat on the one hand and the consumption of heat or power on the other are by no means equivalent in quantity nor coincident in time. Or else attempts have been made to equalise the variations by the introduction of large gasometers, of gigantic lead accumulators or of "Ilgner" flywheels, &c. However, there is an excellent means available for the accumulation of energy up to any desired amount, viz., that of storing steam in water under increasing pressure and discharging it under falling pressure. Although this method is fairly generally known, it has not hitherto, owing to certain prevalent prejudices, been applied in practice to the extent that it deserves.

The utilisation of this method in a rational manner pre-supposes that variations of pressure ranging up to several atmospheres should be attainable. As a matter of fact, every steam boiler of very large water content could in principle be arranged as an accumulator of this kind, but in order that the boiler may act as an equaliser, it must be constructed for a pressure far above the normal working pressure, so that variations between the maximum and the normal working pressure may be attained. The fact that no such increased pressure has been provided for, but that, on the contrary, the boilers are usually constructed for a pressure only so much higher than the steam pressure needed as corresponds to the pressure drop in the pipe lines, proves that the principle referred to has never been carried through completely in practice.

As, with constant boiler pressure, no accumulator action is possible, it follows that the quantity of heat conveyed from the fire to the heating surface per unit of time must likewise exactly correspond to the amount of steam that the boiler is required to supply. It is therefore evident that the variations in the steam demand must cause corresponding variations in the fuel supply to the boiler. It is evident that many boilers of older systems possessed a certain but limited capacity for accumulation. In boilers of more modern types, however, the water space is far too small for any equalisation of variations worth mentioning. Attempts have been made to increase the water space in water-tube boilers (*e.g.*, MacNicol type); owing, however, to difficulties encountered in construction, this result could only be attained at the expense of the amount of steam pressure, so that boilers of that kind are, in fact, merely a sort of compromise between the old cylindrical boiler and the new water-tube boiler.

Thus, on the one hand, attempts were made to obtain equalisation in the boilers, but on the other, it has been tacitly assumed that the pressure should be kept constant, and for this reason, of course, no accumulation was possible.

The only correct solution of the problem of rational steam utilisation is to employ the steam boiler exclusively as the steam generating agent, and to dispense entirely with the use of the boiler as an accumulator. Accordingly, the steam generator should be built with very small water space, or even with none at all—in the latest constructions the steam generator is, indeed, practically speaking simply a coiled pipe—and should be worked at an absolutely steady high pressure. Instead of every common type of boiler, at present having its own water tank, which consequently must be built to stand the full boiler pressure, the water spaces of all the individual boilers should be, so to say, united into one tank, which is entirely separated from the boilers and well insulated against

Fig. 1.

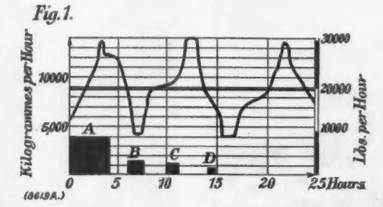
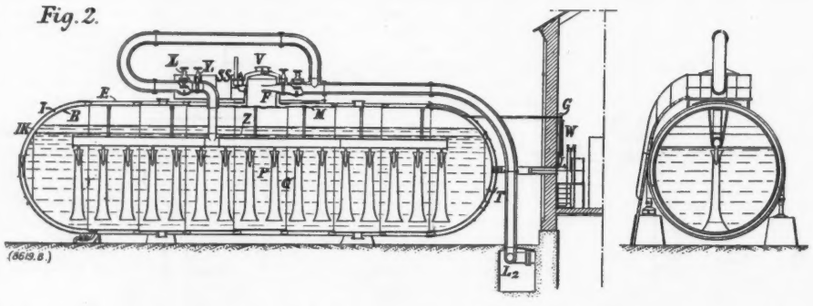


Diagram of rate of steam consumption of a factory and the possible elimination of variations through the installation of a Ruths accumulator (A), flue boilers (B), MacNicol water tube boilers (C), and standard water-tube boilers (D). In the first case the boiler pressure remains constant, in the other it varies by 20 per cent.

Fig. 2.



loss of heat. In such tanks, usually built for pressures lower than those of the boilers, a much larger variation of pressure is attainable than in the boilers. Furthermore, these tanks can be built of any size whatever, irrespective of the type of boilers used or of the size of their heating surface.

The accumulation of steam in water and its subsequent evaporation is a well-known principle and has for a long time past been used by practical engineers; in this connection reference may be made, for instance, to the Rateau accumulators and also the feed water accumulators by Druitt Halpin and others. The direct storage of steam without water has also been effected in practice both in containers of constant volume and in containers of variable volume.

In all the cases just mentioned, however, with the exception of the feed water storage systems, the definite aim in view is that of accumulating the exhaust steam of hoisting engines, of rolling-mill engines, &c. where the work proceeds intermittently, so as to make it possible to pass the exhaust steam from these engines into continuously working low-pressure turbines, even during the intervals when the main engines are at rest. The author, however, did not want to confine himself merely to the saving of exhaust steam, as Rateau and other engineers had done, but set himself the problem of overhauling the entire heat and power economy of industry, from the point of view of the accumulation of steam in water.

The Equalising Ability of Steam Boilers of Various Types as Compared with that of the Accumulators.—As a consequence of the fact that the extent of the variations actually existing in industrial plants is not generally known, there is a tendency to suppose that a sufficient accumulation of steam could equally well be made in the steam boilers themselves. In order to make the thing clear, there are below shown some calculations, based upon a typical diagram of steam consumption as obtained in practice.

The demand of steam varies in a particular case (see Fig. 1) between 8,800 and 31,000 lb. per hour, with an average of 19,400 lb. per hour. The diagram shows how large are the areas between the curve and the line of mean consumption, *i.e.*, lb. of steam, which have to be equalised in such a typical case if the boilers are to work at the constant average load.

A boiler plant big enough to deliver the maximum amount of steam required, 31,000 lb. per hour, would, when using normal boilers of the Lancashire, the MacNicol and the common water-tube type, have sizes of 5,800, 5,800 and 4,500 sq. ft. respectively.

If as big a pressure drop as 20 per cent. should be permitted at peak-loads the extra steam given off by the water of the boilers on such occasions would, however, amount to only 3,900 lb., 2,400 lb., and 825 lb., respectively, whereas if the system of steam accumulation here discussed were adopted, an accumulator of a capacity corresponding to the 35,000 lb. of steam that are needed for the full equalisation of the boiler load, would be installed.

In Fig. 1 the storage capacity of the accumulator needed, and that of the boilers specified above, is shown by four squares A, B, C and D, drawn to the same scale as the steam diagram. From this it is evident that when great variations exist in a steam system the equalisation problem can never be solved by boilers alone, but only by means of a steam accumulator working in conjunction with, although separated from, the boilers. This method offers the additional advantage that the pressure in the boilers remains perfectly constant, whereas, in the case of the direct storage or accumulation of steam in the boilers as in cases B, C and D, the pressure, as mentioned, is bound to vary considerably more than generally can be admitted in practice.

Even the Druitt Halpin accumulators and others of similar system, containing feed water which is to be heated by surplus steam from the boilers and which is subsequently to be fed into the boilers during peak loads, are of very little value for practical steam accumulation.

In the particular case under review above, the equalising effect of the accumulator must be eight times that of the flue boilers, about fifteen times that of the MacNicol boilers, and thirty-five times that of the standard water-tube boilers.

It is true that the new kind of steam accumulator may have to be built in sizes hitherto unusual. Thus, for instance, the Swedish firm "Aktiebolaget Vaporackumulator," of Stockholm, has built tanks up to a capacity of 12,000 cub. ft.; in one mill an accumulator of a capacity of no less than 37,000 cub. ft. had to be installed, but it was subdivided into three separate tanks. Whereas the Rateau accumulator and the containers of constant volume or constant pressure, in view of the special purpose for which they are made, work with variations of pressure of some 3 lb. to 5 lb. per square inch, accumulators of the system here described are usually built for very much larger pressure ranges, *e.g.*, from 100 lb. to 30 lb., from 60 lb. to 20 lb. per square inch, and so on. Owing to the larger volumes employed and the much greater pressure variations admitted, these accumulators possess a very much larger storage capacity than those of the other types. Whilst the latter are built with a storage capacity of only a few hundred pounds of steam—an amount quite sufficient for their particular purpose—these accumulators are generally built to hold from 5,000 lb. to 40,000 lb. of steam, and a plant has actually been built to store even as much as about 150,000 lb. There is, of course, practically no maximum limit to the size of such tanks. I may refer to the very big steel "tanks" used as supply pipes for water turbines. Such pipe-lines sometimes have a length of several miles, and a diameter of 17 ft. or more and work under pressures of several atmospheres. Similarly, there is no minimum limit to the size. Accumulators of only 70 cub. ft. capacity have actually been built.

Description of the Accumulator.—The accumulators of the author's system are built in the form of cylindrical containers with hemispherical ends. They are filled with water up to 90-95 per cent. of their capacity. Fig. 2 shows a sectional view of an accumulator.

B is the vessel constructed of riveted steel plates.

* Paper, abridged, contributed to Section D of the World Power Conference on July 3, 1924.

I is a covering of non-conducting material, usually consisting of up to 4 in. of infusorial earth (Kieselguhr) or infusorial earth mixed with cork, or of a magnesia composition. J-K are insulation blocks covering the riveted seams of the shell. They are made removable so as to enable the inspection of the seams, prescribed by the Board of Trade Regulations, to be readily carried out. The lagging is protected by a sheet iron cover E. The accumulators are equipped with the fittings usual in boiler practice and, further, with arrangements for the charge and discharge of steam. These include two non-return valves X_1 and X_2. X_1 admits charging steam to the internal steam distribution pipe Z, and the charging nozzles P, which are equipped with the circulation pipes Q to insure a uniform heating of the water. Through valve X_2 the discharge of steam takes place.

The heat losses of the accumulators are considerably less than is generally imagined, and as a matter of fact so small, that they are of no practical consequence. Results of insulation tests made on accumulators in practice show that, with the thicknesses generally made use of, the heat losses only correspond to from 0·1 to 0·5 per cent. of the coal consumption of the boilers, and are therefore of no practical importance at all. That being so, the accumulators are usually erected in the open air, and often at some distance from the boiler-house, in factory yards, etc.

From the above description it is evident that the accumulator, although it can be charged with superheated as well as with saturated steam, can only deliver saturated steam. In certain cases, however, it is desirable to have an accumulator that can also deliver superheated steam. This is of great value, especially in plants where the accumulator has to feed such consumers as steam engines, steam turbines, steam hammers, &c., which utilise the energy of steam for the production of motive power. The possibility of feeding such consumers with superheated, steam means a considerably lower steam consumption, and hence also a reduction in the accumulator capacity needed.

This problem has been solved by adding to the steam accumulator a second container, so designed that it works on the same principle as the well-known Siemens regenerative heater used in connection with metallurgical furnaces for preheating the gas and the air of combustion. The accumulator for superheated steam thus consists of two separate containers, one for storing the superheat and one for the storage of the latent heat of the steam.

Special Uses of the Accumulator in Power Plants.—Apart from the above stated general value which a steam accumulator has in the numerous plants where there are variations in the demand of steam for heating or for power purposes, or where there are variations in the supply of heat (surplus gas, waste heat, &c.), the accumulator can with advantage be used for a special purpose, in connection with power transmission systems, *e.g.*, those utilising water power.

The combination of a steam accumulator with one or more steam turbines is a very useful means of maintaining a local stand-by working with very small no-load costs and other working expenses. Even in cases of sudden interruptions in the supply of current from long-distance power transmission systems the local load can, if required, be taken over without any delay by a steam turbo-generator, fed by the accumulator, without the necessity of keeping the boilers permanently under steam. The steam accumulator will in such cases take the place of lead batteries.

Further, in the "heavy" industries such as in iron and steel works, where a co-equalisation has to be maintained between the variations in the supply of energy (surplus gas from blast furnaces and coke ovens, waste heat from furnaces and engines) and the fluctuations in the consumption of energy for power purposes, the steam accumulator is of greater commercial and technical value, than, say, the expensive Ilgner type plants and the storing of the low-grade blast furnace gas in gasometers. It is interesting to note in the latter connection that 1 lb. of steam which, when stored in a steam accumulator, occupies 0·02 of a cubic foot, corresponds in thermal value to about 16 cubic feet of blast furnace gas.

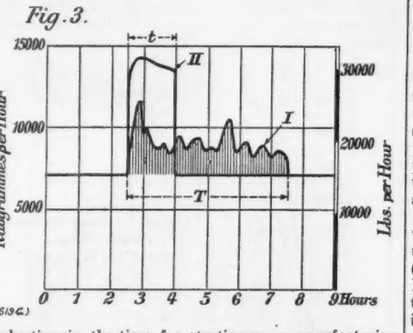
Results Obtained in Practice.—In a factory or power station equipped with an accumulator, steam can at will be supplied at any time at an unlimited rate should it be required in the manufacturing operations or through peak loads in the power distribution system. The manufacturing plant and machinery can thus be fully utilised. For example, a heating process normally consuming steam at the rate shown by Curve I in Fig. 3 (which rate is dependent on the steam supply from the boilers) can be intensified by accumulated steam to the high rate shown by Curve II, whereby the time $T-t$ is saved.

Improved and More Uniform Quality of the Product.—Lack of steam often occurs in factories just when an increased supply of steam is badly needed for the carrying through of a manufacturing process. The process is then delayed or the quality of the stuff lowered. It must be borne in mind that as a rule, of two operations proceeding simultaneously, the cruder process, such as "heating-up," &c., will generally use steam to the detriment of the more refined operations, like drying or chemical processes.

Increased Economy in the Consumption of Fuel.—By the action of a steam accumulator the peak-loads are taken off the boilers and their pressure kept constant. This means that mechanical stoking can be generally adopted, and the boiler staff is able to devote all its time and attention to keeping up the most favourable combustion of the fuel. Great fuel economy results, together with more even working and less wear and tear.

Increased Yield of "Back Pressure Power" from Heating Steam.—The accumulator furnishes the possibility of keeping the boiler pressure constant, and just below the blow-off pressure of the safety valves, which fact has a very favourable influence on the output of back-pressure turbines or engines. Moreover, the output of the high pressure stage of an extraction turbine or of a simple back pressure turbine is materially increased by the equalising influence of the accumulator, as with the constant steam flow from the boilers through the turbine, very small losses occur in potential energy of the steam by throttling. If a back-pressure extraction-power system does not comprise an

Fig. 3.



Reduction in the time for starting-up a manufacturing process after installation of a Ruths accumulator. Curve I: Protracted steam diagram before installation of accumulator. Curve II. The same diagram with accumulator.

accumulator and the fluctuating steam flow to the consumers is as usual led through the back-pressure turbine or the high-pressure stage of the extraction turbine, it must be run at a variable load and consequently great throttling losses result.

The action of the accumulator effects a further gain in the output of such a turbine from the fact that, despite all the variations in the steam demand, practically all the steam produced by the boilers is conveyed through the turbine. It very often occurs in such plants when not provided with an accumulator, that large quantities of heating-steam have to be by-passed direct from the boilers without power generation, as it is usually not of advantage economically to make the turbine of such a size that it can pass the maximum demands of heating-steam which occur for instance only when digesters are started, dyeing vats are heated up, &c.

Even in the case of a steam power plant, from which no steam is abstracted or exhausted for heating purposes, as, for instance in an ordinary power station, there is no loss of power by the insertion of an accumulator (which may be arranged for superheated steam) between two turbine stages.

As the boiler pressure as well as the superheat are automatically kept at their maximum values by the accumulator and as, further, the efficiency of the high-pressure stage is practically constant, though the accumulator pressure varies, and as also the low-pressure stage—especially if it is equipped with automatic nozzle control—utilises the steam from the accumulator without extra losses, the total heat drop available is not less with an accumulator introduced between two turbine stages than it would be without it. At most, the heat drop is reduced by an amount corresponding to the extra back pressure caused by the water-head above the nozzles in the accumulator. This head, however, is small, so that the loss entailed is of no practical importance.

PARTICULARS OF BRITISH WARSHIPS.—A Blue-book, giving the principal dimensions, particulars of armament, speed, and other data relating to all classes of vessels of H.M. Navy, and also to the vessels of the naval forces of the Dominions, has just been issued, and is now on sale at any of the branches of H.M. Stationery Office at the price of 10*s.* net.

STEAM TURBINES FOR HIGH PRESSURES.*

By C. F. STORK.

ESPECIALLY of late years, as far as the larger units are concerned, the designers of disc turbines have had to cope with difficulties resulting from high stresses of material and corrosion of the blades in the low-pressure parts of the turbines. It has proved to be a rather difficult matter to find the happy mean between the various requirements that must be made for a good turbine—high economy, to be attained by high steam pressure and high superheating on the one side and safety of working on the other side.

Even in authoritative technical literature it has been proclaimed that a steam turbine, as a rule, will not work very economically in the area of the higher steam pressure, and for that reason the designers have tried to use the low-pressure area to the best possible advantage by raising the vacuum to the utmost. It is evident that a considerable improvement would be obtained if makers could succeed in reconstructing the high-pressure and high-temperature area so as to attain a favourable economy.

There are three points to be investigated:—(1) Is it possible to reduce the steam consumption, or rather the heat consumption, of the turbine? (2) Is it possible to improve the economy at partial load? (3) Is it possible to improve the reliability, especially in the larger units?

Up to the present time a maximum pressure of about 18 kg./cm.² (250 lb. per square inch) and superheating up to about 375 deg. C. (710 deg. F.) have been used almost exclusively. Such pressure and temperature are lowered as soon as possible in one Curtis wheel or in one or two large single-bladed impulse wheels. At full load the pressure after the first expansion stage usually is only 5 to 6 kg./cm.² (70 to 85 lb. per square inch), and this pressure is diminished proportionally at partial loads. Even at full load this expansion is not economical, and it is still worse at partial load.

Only after the first stage does the turbine begin to work more economically. In fact, it may be said that up to the present time low-pressure steam turbines (exhaust turbines) have been used. The "Erste Brünner Maschinenfabrik" (Czecho-Slovakia) came to the conclusion that the heat consumption can be improved, mainly by increasing the heat drop in the area of high pressure and by building a very economical turbine for this area.

The turbine designs that are known and have been executed cannot in an economical way take advantage of the heat drop when this is increased in an upward direction; it is characteristic of all of them that in the first expansion stage the steam will expand to a low pressure in order to get low steam pressures and low temperatures in the casing. Many firms will even mention this as an advantage. It is, however, clear that such a high-pressure part, which even now works much less economically than the low-pressure part, may be called useless in the area of the higher pressures.

It is a well-known fact that for the Parsons turbines and the reaction turbines a quality figure has already been introduced which is applied by Brünn as a quality figure for the whole turbine. This is the coefficient $\frac{\Sigma U^2}{H}$, H being the total heat drop and ΣU^2 the sum of the squares of the circumferential speeds of the blades which utilise the heat drop H. This quality figure is, in fact, a measure of the relation between the square of the circumferential blade speed and the square of the steam velocity that can result from the heat drop.

Investigation shows that all present turbines are defective in so far as the quality figure for the high-pressure part is concerned, and that this figure is considerably worse than the figure for the low-pressure part. It is, properly speaking, expected that the low-pressure part will make up for the losses in the high-pressure part. In order to make use of the high-pressure heat drop in a steam turbine to a degree of efficiency that will be at least equal to the efficiency of the low-pressure heat drop, it has been proved necessary to raise the quality figure of the existing constructions to a very considerable extent so that the values of the low-pressure part are reached and exceeded. This improvement will be brought about if the high-pressure part is taken out of the existing single-cylinder turbine and developed into a special high-pressure turbine.

After long experiments, the Erste Brünner Maschinenfabrik has built a high-pressure turbine, and the diagram on the next page shows the comparison in the expansion stages of the efficiency as compared with the efficiency of ordinary impulse wheels with a single row of blades. The new design is characterised by the flat course of the top of the efficiency curve, which is very important for variable loads.

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* Paper, abridged, contributed to Section D of the World Power Conference on July 4, 1924.

Should it be possible to keep the losses that are not important for the low pressure part (for instance, wheel friction, ventilation, surging shocks, &c.), very low also for the high pressure part, the steam and heat consumption of the turbine then would be reduced considerably; in the first place because a greater heat drop is used in the turbine, in the second place because in the extended high-pressure area the heat is used more economically.

A proof of the accuracy of these statements and of the possibility of attaining these results was obtained by the exhaustive examination of a back pressure turbine of about 2,300 kw. built by the E.B. Maschinenfabrik for the Nestomitz Sugar Mill. This examination was made by Prof. Josse, of Berlin, Prof. Dresden, of Delft, and Prof. Niethammer, of Prague, and was published in the *Ingenieur* of June 30, 1923. Subsequently, this turbine was examined again by Professor Dr. A. Stodola, of Zürich, by means of his own Swiss instruments and with his own assistants exclusively. At these last mentioned trials, several representatives of competing firms were present. The former observations were absolutely confirmed. At full load the diagram efficiency was found to be 84·2 per cent., and the overall efficiency 82·4 per cent.

It is also worth mentioning that the turbine from the start was running at 400 deg. C. (750 deg. F.) superheat and more, and that this temperature was exceeded also at the trials.

Now we may ask how this efficiency of this type of turbine has been reached. The trials have shown that a high quality figure $\frac{\Sigma U^2}{H}$ is needed for the high pressure part, but that it is by no means immaterial in what way this is reached; in other words, that it is one thing to use the heat drop in one large wheel, or in a few large wheels, with high circumferential speeds, and another to use the same heat drop in a greater number of small wheels with low circumferential speeds. It proved to be the first essential point that the wheels should obtain steam around the whole periphery. If this does not happen, the part where there is no admission will have such a ventilating effect that the flowing of the steam in the admission part will be seriously interfered with.

In the second place, more than 50 steam flow trials have shown that transition of the steam to a different diameter will cause surging shocks, even at velocities far below the velocity of sound. These surging shocks at the same velocities are more violent as the steam becomes greater in density, as the radius of curvature of the steam course is smaller, and as the transitions between the different diameters occur less gradually.

These trials completely explained the phenomenon that, up to this time, back pressure turbines have never been so economical as low pressure condensing steam turbines, even when the relation U/Co has been taken at absolutely the same value. The result of the trials has shown that it is essential for a high pressure turbine that the steam velocity should be taken lower as the steam density (and consequently the steam pressure) becomes higher.

At these trials a great many details were brought out to which close attention should be paid, relative to the shaping of the guide and running blades; but in the first place the high-pressure turbine must be built for admission of steam along the whole periphery and for small steam velocities.

Whereas, in the designs at present in use, the steam in the first stage, expands mostly to about 6 kg./cm.² (85 lbs./sq. inch) with a volume of about 0·33 m.³ per kilogram (5·3 cub. ft./lb.) of steam, this volume in a good high-pressure turbine at an initial pressure of 35 atm. (500 lbs./sq. inch) will be about 0·09 m.³ per kg. (1·4 cub. ft./lb.), and at 50 atm. (700 lbs./sq. inch) about 0·06 m.³ per kg. (0·93 cub. ft./lb.).

The guide channels for these turbines are made very accurately, and consequently the results, as to the relation between the theoretical and the actual velocity of discharge, are very favourable. Moreover, the design allows of using non-corrosive material. A great number of trials and the practical operation of turbines have shown that in the high-pressure area at least the same economy can be attained as in the low-pressure area. We thus see that the high-pressure area can be used with good efficiency, and that this is another way of enhancing the economy of the cycle.

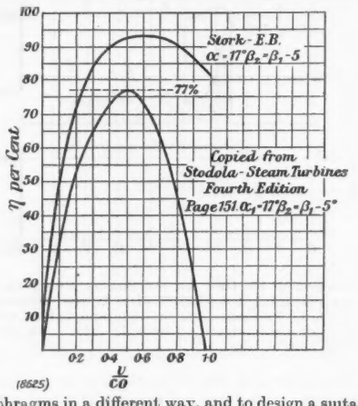
We now come to the second question, viz., whether it be possible to improve upon the economy at partial load. The greater number of turbines, especially in electrical power plants, will run at loads that are variable to a great extent, and any turbine that shows a flat economy curve, *i.e.*, that does not show a great difference of steam consumption between full charge and for instance, quarter charge, will be superior to others. There is only one way to give this curve a favourable aspect, namely, by keeping the pressure after the first guide disc as high as possible, in other words, by seeing that in the first stage the expansion will be as slight as possible.

The usual turbine designs do not satisfy this requirement, neither are they able to do so. The large turbine casings with large diameter diaphragms and large diameter stuffing boxes are by no means reliable when high steam pressures and high temperatures are applied. The so-called "governing by cutting out nozzles" before the first stage is not a standard for economy at partial load.

If the first expansion stage utilises a great heat drop (which unavoidably will be incidental to a lower economy at full load), then this heat drop will be ever increasing as the load decreases. The pressures in the different stages decrease approximately in the same ratio as the load; in other words, at quarter load the pressure after the first stage will be lowered to about quarter of the pressure at full load. The less the load the more the expansion stages after the first stage are eliminated and the greater the part of the energy that has to be taken up by the first stage. Moreover, the economy of this stage will suffer a great loss, as the ratio U/Co will become gradually worse.

If, on the other hand, the pressure after the first stage is kept very high, this pressure, even at partial load, will remain high, and then the expansion stages after the first stage can utilise a great part of the heat drop to high economy. In that case the economy curve must be a great deal flatter than the curve of a turbine with throttle governing or a turbine governed by cutting out nozzles and with a great heat drop in the first stage.

In order to allow high steam pressures and high temperatures after the first stage, it has been necessary to make a different design for the casing, to insert the



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diaphragms in a different way, and to design a suitable gland. The diaphragms are placed in loose bushes with self-tightening seams. These suspended bushes are heated up to the same temperature as the internal parts by the surrounding steam flow. The whole is enclosed in a small cylinder that may be considered as a staying casing of a simple shape. For high initial pressures, for instance, of 50 to 100 atm. (700 to 1,400 lbs./sq. inch), this casing is of pressed steel. The economy at partial loads can be improved by applying a high steam pressure after the first stage. The design has been made in accordance with this principle.

In conclusion, the third question is left to be answered: whether it be possible to improve reliability, especially in large units. It is a very favourable circumstance that the results that have been attained for the most favourable flow of the steam will, at the same time, bring about the highest possible degree of reliability. In order to obtain the most favourable hydraulic effect we must apply low steam velocities. It is not advisable for us to draw our conclusions exclusively from the hydraulic efficiency, viz., from the favourable flow through the blades. The additional losses ought to be investigated, especially for steam of great density.

Hydraulically, the Parsons blade with about 50 per cent. reaction is excellent. But in the high-pressure turbine it is extremely difficult to lessen the secondary losses, such as leakage, &c., whereas the reliability should not be jeopardised by infinitesimal clearances. The high-pressure rotor has been built as a disc rotor, the shaft and the discs forming one solid forging. The sealing of the different expansion stages is effected by labyrinth glands in the diaphragms. The distance between the bearings is very small, so that even for 3,000 r.p.m. the shaft has been made as a "rigid shaft," in other words, the turbine will run below the critical number of revolutions. The discs, being of very small diameter, have a low peripheral speed and are very rigid. The critical speed lies far above the actual number of revolutions.

The cylinder is of very small length overall and small diameter, and consequently can easily stand the high steam pressures. When very high steam pressure is applied, the intermediate pressure cylinder is built in the same way. The low-pressure part, where the blades already have attained sufficient length, is made as a reaction cylinder with moderate blade speed. The advantages of the good hydraulic flow can be utilised here to their full extent, whereas the short and rigid cylinder, at the very low initial temperature, offers an exceedingly great reliability. This low-pressure part, too, has been designed with special care.

From the above it will be evident that the advantages of the Erste-Brünner design are very important, and it will cause no surprise that a number of Continental steam turbine manufacturers have decided to construct this turbine under licence of the inventors. The Dutch licensees have already supplied, and are now making, various turbines for the Netherlands, its colonies, and for Belgium.

As an example of the results that have already been attained, we may mention that a back-pressure turbine of 750 kw. has been made and carefully tested by the Engineering Works Gebr. Stork and Company. With a steam pressure of 7·25 kg./cm.² (103 lb. per square inch), a temperature of 325 deg. C. (617 deg. F.) and a back pressure of 0·7 kg./cm.² (10 lb. per square inch), a steam consumption of 14·2 kg. (31·2 lb. per kw.) at full load was found, corresponding to an overall efficiency of 77 per cent. for the turbine only.

This figure is very favourable, as it must be taken into account that the turbine was constructed to be able to work with a great overload and consequently the efficiency at normal load had to suffer. If this had not been the case an overall efficiency of 80 per cent. could have been attained, which may rise in other cases to 85 per cent.

At present a turbine of 16,000 kw. is in course of construction for a steam pressure of 35 kg./cm.² (500 lb. sq. in.) and a superheat of 400 deg. C. (750 deg. F.). For this turbine a steam consumption of 3·83 kg. (8·44 lb.) per kw. has been guaranteed, corresponding to an overall efficiency of 86 per cent. for the turbine alone.

STEEL PIPES FOR SOUTH AFRICA.—H.M. Senior Trade Commissioner in South Africa has forwarded to the Department of Overseas Trade a copy of the general conditions, specifications and form of tender for the supply and delivery of steel pipes, valves and specials for the Vereeniging-Zwartkopjes Pipe Line (Contract No. 257). The material in question is required in connection with the second 5-million unit of the Vaal River scheme of the Rand Water Board. Tenders must be delivered in Johannesburg before noon on Friday, September 5, and are to be accompanied by a certified cheque or cash deposit for £1,000, which may be retained if the contractor withdraws his offer within six weeks of the date on which tenders are opened. United Kingdom firms in a position to supply British materials can obtain further particulars of this call for tenders on application to the Department, 35, Old Queen Street, S.W.1, quoting reference A. X. 1102.

THE ROYAL TECHNICAL COLLEGE, GLASGOW.—Instead of making a new appointment to the chair of Mechanics in the Royal Technical College, Glasgow, made vacant by the greatly regretted death of Professor J. G. Longbottom, the Governors have wisely decided to amalgamate the Departments of Mechanics and Mechanical Engineering. Under the new arrangement, Dr. Mellanby becomes Professor of Mechanics and Mechanical Engineering, and Dr. William Kerr has been appointed Associate Professor in the same Department. All who are familiar with the excellent work done by Dr. Kerr in the solution of steam turbine problems will find pleasure in this recognition of his abilities as an engineer, a mathematician and an experimental investigator. Dr. Kerr served his apprenticeship with Messrs. Murray and Paterson, Limited, of Coatbridge, and was afterwards employed by the firm as a draughtsman, pursuing his studies at the Royal Technical College on the sandwich system during some of these years. Obtaining the Beilby Research Scholarship in 1911, he conducted research work in Professor Mellanby's laboratory for two years, during which period he investigated many problems relating to steam turbines, the results of which were given in papers on the "Steam Friction of Turbine Wheels" (see ENGINEERING, vol. xcvi, page 268), the "Calculation of Centrifugal Stresses in Turbine Rotors," and the "Whirling Speeds of Loaded Shafts," a serial article contributed to ENGINEERING (vol. ci, starting on page 150). In 1913, Dr. Kerr entered the design office of the Fairfield Shipbuilding and Engineering Company, Limited, and was engaged upon the design of turbines and gearing for naval and merchant vessels. During this period he was also associated with the staff of Messrs. John Brown and Co., Limited, Clydebank, in developing the designs of Brown-Curtis turbines for installation on Fairfield-built vessels. When he became research assistant to Dr. Mellanby in 1919, his services were retained for some time in a consulting capacity by the Fairfield Company, and since then have been sought by other concerns in dealing with intricate turbine problems. During the last five years Dr. Kerr has been closely associated with Dr. Mellanby in fundamental engineering investigations, and they have contributed jointly many papers to the leading institutions of the country concerned with engineering and shipbuilding. In 1923 the degree of Ph.D. was conferred by Glasgow University upon Professor Kerr for a thesis consisting of nine parts, each dealing with some phase of his recent experimental work.

5,000-KW. BRUSH-LJUNGSTRÖM TURBINE; BRITISH EMPIRE EXHIBITION.

CONSTRUCTED BY THE BRUSH ELECTRICAL ENGINEERING COMPANY, LIMITED, ENGINEERS, LOUGHBOROUGH.

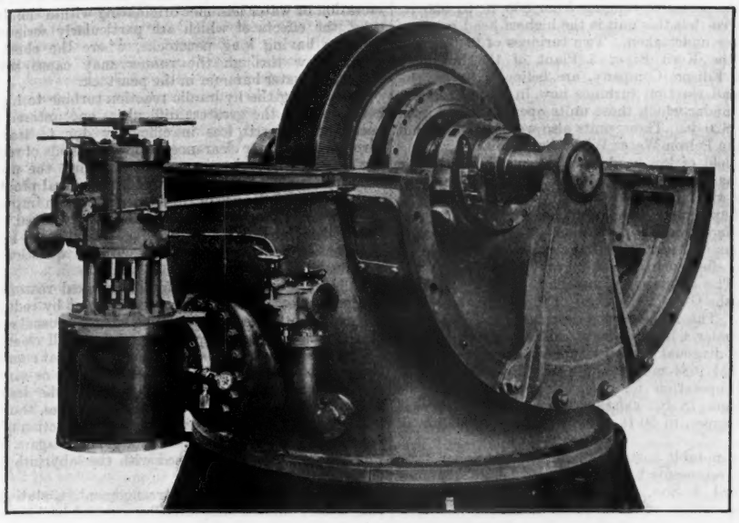

FIG. 1. TURBINE WITH UPPER PART OF CASING REMOVED.

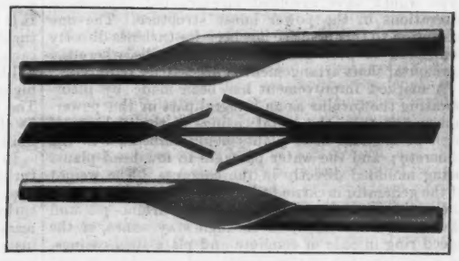

FIG. 2. HALVES OF STATOR-CONDUCTOR, WITH INSULATION, DISASSEMBLED.

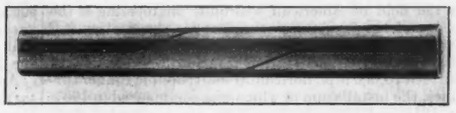

FIG. 3. HALVES OF STATOR-CONDUCTOR FITTED TOGETHER.

5,000-KW. BRUSH-LJUNGSTRÖM TURBINE AT THE BRITISH EMPIRE EXHIBITION.

IT is now over fourteen years since we published full working drawings of the first Ljungström turbo-generator ever constructed, a machine of 1,000 kw. capacity, which was shortly afterwards brought to this country and put down in a London power station. It is, we believe, still giving good service. The Brush Electrical Engineering Company, Limited, of Loughborough, about that time, acquired the rights for the development of the type in this country, and the Brush-Ljungström turbine has been recognised for many years as unequalled in economy by any other type for the sizes in which it is constructed. The machines are now so well known, as embodying the radial-flow double-rotation principle, that any detailed description is unnecessary, but the extraordinarily small dimensions of a turbine of the type in question are well brought home to visitors to Wembley by an inspection of a 5,000-kw. machine exhibited there on the Brush Company's stand. We illustrate this exhibit in Figs. 1 to 4 on this page. The turbine proper consists of concentric-blade rings located between the two rows of radial blades which figure so prominently in Fig. 1. The radial blades are the last through which the steam passes on its way to the exhaust, and the diameter of the bottom flange of the casting, which forms the connection to the condenser, serves to indicate, by comparison, how relatively small the turbine is. The half-flange in the foreground of the illustration is bolted to the alternator, the other half being, of course, on the upper part of the turbine casing. For exhibition purposes, the turbine is supported by a temporary cast-iron bracket at each end, as shown. A 5,000-kw. Brush-Ljungström turbine unit measures only 28 ft. 6 in. in extreme length over both alternators, and the centre line of the shaft is at a height of 4 ft. above the floor level. With a basement floor 16 ft. below the engine-room floor, there is ample head room for condensing plant and auxiliaries, while a crane hook 13 ft. above the engine-room floor gives plenty of clearance for dismantling and reassembling the plant.

An interesting example of a low-pressure Brush-Ljungström turbo-generator has been running for some time in a large textile mill in Scotland with very satisfactory results, and a duplicate set has now been installed. The set consists of a Brush-Ljungström turbo-generator having an output of 7,150 k.v.a., three-phase, 50 periods, 525 volts, power factor 0·7, with an overload capacity of 25 per cent. for two hours. The current per phase is 8,000 amperes. The usual design of the turbine has been followed in this case, the only special feature of the plant being the alternator, and especially the construction adopted for the stator winding in view of the heavy current involved.

The Brush-Ljungström turbo-generator possesses natural advantages when required for low voltages in that the total output is divided between two alternators. The limit in output for efficient design at a predetermined pressure is therefore twice that of a

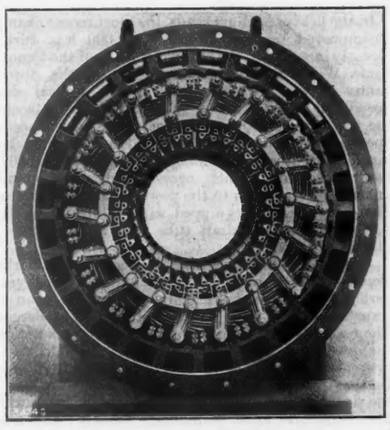

FIG. 4. END VIEW OF STATOR.

turbo-generator with a single alternator. The current per phase of each alternator is 4,000 amperes, and as it is impossible to subdivide the winding to any extent, a heavy current per slot is unavoidable. Special precautions, therefore, have to be taken to avoid eddy currents and overheating. Although the usual method of winding adopted for low-pressure machines—viz., compressed stranded cable and multiple-strip conductors—is satisfactory up to a certain point, it has disadvantages, particularly that of lack of rigidity.

To overcome the disadvantages of the usual method of winding, a split tubular conductor has been evolved. This conductor, illustrated in Figs. 2 and 3, above, consists of a hard-drawn copper tube split in such a manner that the eddy current losses are reduced to a minimum. Each half of the tube forms a separate conductor, the two conductors forming two parallel circuits in each phase winding and being insulated from each other by highly compressed fibre. After this insulation is in position, the two halves of the tube are mica-moulded under heavy pressure at a high temperature. Thus the slot bar—consisting of two conductors—is practically solid, and approximates very closely to the ideal mechanical construction for windings.

Extreme care is taken in making the connections between machines and also to the bus-bars, as with the heavy current involved, there is considerable danger of heating in any iron parts near which the leads pass, due to eddy currents being set up in these parts. Each phase current was divided between two leads, making six leads in all, and these leads so interspaced that the resulting field is negligible. After erection, the connections were tested with a current of 10,000 amperes without any excessive heating either in the leads themselves or in any adjacent portions of the plant. Fig. 2 shows the two halves separated, and the fibre insulation which separates them, while Fig. 3 shows the two halves fitted together.

In Fig. 4, which is reproduced from a photograph of the completed stator, the hollow conductors are clearly shown, also the end connections, which consist of single copper bars of heavy section held rigidly in clamps. It will be noticed that each slot conductor can be disconnected by unsweating the end connector at one end and unbolting at the other without disturbing any other portion of the winding. Each bar was tested at a pressure of 5,000 volts before being connected up (525 volts being the working pressure) and in order to ascertain the factor of safety in the insulation, one bar was tested to destruction. This bar finally broke down under a pressure of 30,000 volts.

It is pointed out by the manufacturers that the advantages to be gained by adopting this type of low-tension winding in preference to the more usual high-pressure coil winding, are considerable. In the first place, there is no possibility of breakdown between turns in the coils as there is the equivalent of one conductor per slot, and the insulation, being pressed on to a continuous copper surface, is reduced to the minimum quantity required. Thus, the clearance necessary in the slots is practically negligible. This ensures a much better mechanical job than is the case where the copper is separated from the iron of the slot by a cushion of relatively flexible material, in some cases at least a quarter of an inch thick. The end connectors consist of single copper strips of heavy section which can be held quite rigidly in the clamps and there is no possibility of troubles due to short circuits. When it is remembered that on turbo-generators the stator winding is usually the most vulnerable part of the machine, this point is worthy of great consideration. Each slot conductor and end connector can be disconnected and replaced quite simply, should this be required. The point of perhaps the greatest importance is that there is a passage of cooling air through the conductor which gives direct contact cooling over its entire length.

Moreover, as a thermometer can be pushed right into the conductor, the actual temperature can be definitely measured. Windings of the type in question can be used over a fairly wide range of voltages and outputs, and their advantages certainly deserve consideration when the conditions are suitable.

THE HYDRAULIC REACTION TURBINE.*

By H. BIRCHARD TAYLOR, M.A.S.M.E., M.S.N.A.M.E.

ONE of the most pronounced characteristics of American practice has been the adoption of the vertical-shaft, single-runner type of turbine. This type has become practically standard for both high and low

* Paper, abridged, contributed to Section B of the World Power Conference on July 4, 1924.

heads and for all except very small units. The only large installations in which horizontal shaft turbines have been installed within the past ten years or more have been in plants containing existing foundations for future horizontal units where the change to the vertical type would have involved unwarranted expense in alterations in the power house structure. The one exception to this practice has been for turbines directly connected to pulp grinders in paper mills, where the horizontal shaft arrangement is necessarily required.

A marked improvement has been made by incorporating the turbine as an integral part in the power-house structure, the metal casings of the turbines of high or medium head plants being embedded in the concrete; and the water passages in low head plants being moulded directly in the concrete. The weight of the generator is carried vertically downward through the solid concrete surrounding the turbine pit and thence to the foundation through stay vanes, or the speed ring in case of concrete and plate steel casings, or a combination of stay vanes and cast steel or cast iron casings for higher head turbines. The American type of setting insures great rigidity of structure and freedom from vibration, and at the same time secures compactness and minimum dimensions of both power-house and substructure.

The most representative example of present practice in the field of American hydraulic engineering is the design of the 70,000 h.p. turbines for the Station 3-C extension of the Niagara Falls Power Company. The older portion of this station (Station 3-A) consists of thirteen 10,000 h.p., horizontal shaft, double runner turbines, the installation of which was commenced in 1907. In 1918 and 1919 (Station 3-B), the horizontal shaft arrangement was abandoned and three vertical shaft single-runner turbines, rated at 37,500 h.p., were installed. In Station 3-C, which is now nearing completion, three new 70,000 h.p. units are installed, establishing a new world's record for size and capacity.

Except for very low heads, the volute or spiral casing is standard practice, and even with very low heads various approximations to the spiral casing are used. In several instances under extremely low heads there is not sufficient vertical space below headwater to submerge the turbine properly without expensive excavation in the tail race, and for this condition a syphon setting is employed. As the head increases, the water passages may be completely enclosed, and the volute type of concrete casing becomes the normal practice.

The speed ring, or stay vane ring, is used in connection with various types of casings to serve as a support for the generator and at the same time to direct the flow effectively. In low head installations where concrete casings are used, the stay vanes are sometimes cast separately and set independently in the concrete rather than being formed in a continuous ring, as is the usual method for higher heads. This results in considerable saving in the metal required for the turbine, with a consequent reduction in cost.

Where the head is too high for the economical use of the standard form of concrete casing, and where the plate steel type may prove expensive, an intermediate form recently developed may be used where the turbine casing is connected to a plate steel penstock. The casing has a circular section and is formed in the concrete, the reinforcing rods being made of similar shape and connected to the speed ring directly. As the head further increases, the plate steel type becomes the preferred practice.

The cast-iron volute casing is very generally used for medium heads, and when low velocities of flow are used stay bolts may be employed to tie together the sides of the casing near the entrance to the guide vanes. The cast iron casing is more generally employed, however, in connection with a speed ring. For extremely high heads, where greater strength is required, the cast-steel casing is used. With very high heads, the stay vanes, instead of being formed in a separate ring bolted to the casing, are cast integrally with the casing, thus giving it additional rigidity and simplifying the design.

In a number of large and important installations a new type of construction, developed by the author, has been used for cast casings. This construction involves the division of the casing into a considerable number of radial sections separated by planes containing the turbine axis. The larger sections are further subdivided by planes, which in turn divide them into two or more sections. The smaller radial sections and the inner subdivisions of the larger sections contain the stay vanes which are cast integrally with the upper and lower casing walls. This construction avoids the necessity for using a separate speed ring or stay vane ring and simplifies the casing construction, and also provides a more rigid structure which is free from distortion and effectively avoids leakage at the joints.

The design of the turbine itself has recently undergone a number of improvements, and its range of application has been extended to heads greatly in excess of those formerly considered suitable for the reaction turbine. The most recent example is the 35,000 h.p. reaction turbine now being constructed for the Oak Grove Development of the Portland Railway, Light and Power Company. This turbine is designed to operate under a normal head of 857 ft., but will be subjected to pressures ranging from 850 ft. to 930 ft. It is believed that this unit is the highest head reaction turbine ever undertaken. Two turbines of 25,000 h.p. each, in the Kern River 3 Plant of the Southern California Edison Company, are believed to be the highest head reaction turbines now in actual service. The head under which these units operate varies from 780 ft. to 820 ft. These units also were designed and built by the Pelton Water Wheel Company.

In the field of low head installations, the hydraulic turbine has undergone radical development, as illustrated by the rapid adoption of the propeller type turbine of extremely high specific speed. The progress made in the introduction of this type of unit in actual installations in America and the improvements which have been effected in its design are particularly noteworthy. The outstanding installation of this type of turbine is the Great Falls Plant of the Manitoba Power Company. The turbines are designed for 28,000 h.p. capacity under a head of 56 ft. and are equipped with the Moody diagonal propeller type runner of a specific speed of 154 (684 metric). These units have been in successful operation for over a year under heads varying from 18 ft., existing when construction was still in progress, to 50 ft., following the completion of the dam.

Another notable installation of the propeller type turbine is represented by the Green Island Plant of Henry Ford & Son, in which the Nagler type of runner, operating under a head of 13 ft., has been installed by the Allis-Chalmers Manufacturing Company. The Nagler type of high-speed propeller runner has been used in a large number of installations, starting as early as 1916.

In the field of medium heads, the most recent example of improved practice is in the 20,000 h.p. turbine recently installed in the Holtwood plant of the Pennsylvania Water and Power Company, on the Susquehanna River. In 1907, units of the vertical shaft, open flume, two-runner design, were installed. Recently the two new 20,000 h.p. turbines have been placed in operation. Each of these latter turbines has been installed in the space originally intended for a 13,500 h.p two-runner unit, which necessitated a considerable amount of alteration to the power house substructure. These turbines are equipped with volute casings and a Moody spreading draft tube with a spiral form of discharge passage.

Among the improvements in the various turbine elements which have been effected in recent years, perhaps none has been more pronounced than the transformation which the draft tube has undergone. The real problem in any draft tube involves not only the question of conserving the energy of whirl, but of preventing this whirl from creating induced losses. In the United States, this problem has been met by the development of two types of draft tubes which have come into great prominence, namely: the White Hydraucone and the Moody spreading draft tube.

There are now in operation or under contract, turbines aggregating 1,200,000 h.p. in which the White hydraucone has been applied, and turbines with a total capacity of 2,000,000 h.p. in which the Moody spreading draft tube has been used.

The White hydraucone and spreading tube are both concentric tubes, the areas being symmetrically disposed about the axis of the turbine. These forms of tube serve to reduce the amount of excavation. In handling the energy of whirl, the spreading tube is superior to the hydraucone, since both components of the whirling water—that is, the meridian and whirl components—are decelerated simultaneously; the first by means of gradually increasing areas and the second by the increasing distance from the axis of the turbine. After the water has passed through the spreading portion it enters the discharge passage which extends around both sides of the spreading portion and equally subdivides the flow. This form of spreading tube has been principally applied to units of low specific speed in which the form of discharge passage is relatively unimportant, since the major portion of the decelerating action takes place in the spreading or symmetrical part of the tube, with the result that the velocity head of the water has been reduced to a low value before entering the discharge passage.

In the tube used in units of high specific speed in which the whirl component has a considerable value, the initial portion is annular, followed by a spiral passage which serves more effectively to regain the energy at the discharge from the annular portion. By the use of this annular form of passage, the water from the runner enters the draft tube without any sudden change in the shape of the section such as exists when the annular form of runner discharge space is followed by a cylindrical draft tube; that is, there is complete continuity of area transition from the runner to the draft tube. The elimination of the central region of the draft tube which is not occupied by the whirling mass of the stream, since the water there is not partaking in the general flow, has resulted in much higher efficiency and has also prevented disturbances such as vibration or water hammer originating within the draft tube, the effects of which are particularly serious in turbines having long penstocks, where the checking of the flow through the runner may cause severe surging or water hammer in the penstock.

In applying the hydraulic reaction turbine to higher heads, one of the greatest difficulties encountered has been the material loss in efficiency due to leakage through the runner clearances. Two methods of reducing this loss have been applied; the first the use of labyrinth seals, which have come into general practice, and the second the use of rubber seal rings, an improvement which has only recently been developed, but which has already been in successful use for a sufficient time to demonstrate without question its practicability.

It is extremely difficult, for mechanical reasons, to reduce the leakage beyond a certain point by reducing the width of the clearance opening when the usual metal seal rings are employed, as an unduly small clearance results in serious risk of seizing due to the heat resulting from contact or due to the presence of grit or sand in the water. The labyrinth seal reduces the leakage by providing several small clearances in series, thus the head effective on each clearance is only a fraction of the total head. The 70,000 h.p. units of the Niagara Falls Power Company are equipped with the labyrinth type of seals.

With the rubber sealing arrangement, a stationary ring of soft rubber, supported by a metal backing, surrounds the runner and comes in close engagement with the metal surface of the runner band. By the use of this arrangement it is possible to provide a much reduced initial clearance, and the flexibility of the rubber avoids the risk of seizure. It has been found that the life of these seals is very much longer than that of the metal seal, even though the water contains large quantities of sand.

Another feature of the turbine which has been materially improved is the design of the main shaft bearing for many large units. American practice, particularly in low head turbines, has favoured the use of *lignum vitæ* guide bearings. This type of bearing is valuable on account of its simplicity and decreased risk of burning out due to interrupted oil supply. The recent improvement in these bearings has been to make them of sectional construction with adjustable shoes, thus enabling the wear to be taken up without the necessity of dismantling the entire bearing and renewing it.

Another recent improvement has been in the design of the operating mechanism, which makes use of a double-acting shearing link for connecting the turbine operating ring to the individual levers of the guide vanes. Such links also permit the use of an offset guide vane lever in place of the usual radial arrangement of lever, which by proper design permits some improvement in the governing characteristics of the unit.

American practice employs, for the most part, the use of a separate governor, belt driven from the main turbine shaft. These governors are designed to function in the usual manner by controlling the pressures in the operating cylinders of the turbine. The use of centrifugal flyballs mounted directly on the main turbine shaft has been successfully developed by Mr. W. M. White, of the Allis-Chalmers Manufacturing Company. With this arrangement of governor, the movement of the flyballs is transmitted through a series of levers to the governor actuator in which are contained the control valves. Another interesting method of governor drive is the use of a separate electric motor directly connected to the governor spindle and supplied with current from the main generator circuit. This type has been successfully employed by the Woodward Governor Company.

An interesting feature of the recent improvements in hydraulic turbine governors has been the perfecting of the remote control for use with automatic generating stations. A number of such stations of capacities ranging up to 5,000 kw. have been in successful operation for several years. This type of plant is rapidly growing in popularity since it makes the development of small water powers an economical proposition by the elimination of the attendance formerly considered necessary.

The means for supplying the pressure for the governor system are also worthy of note. In large plants, where there are a number of units, a central pumping system is usually employed, although individual pumps and accumulator tanks are frequently used. The Pelton Water Wheel Company have recently developed a special gear type pumping unit for oil systems which may be applied to either of the two particular classes of systems. In central systems, water is frequently used in place of oil as the medium for transmitting the

power to the operating cylinders, and, in order to prevent corrosion of pipes and valves, a solution of potassium bichromate is frequently employed; as an alternative, the use of soluble oil with the water has grown in favour.

Considerable increase in first cost of the installation is justified for the purpose of eliminating the complication and waste of water involved by the addition of relief valves. In many installations having long penstocks, however, relief valves are necessary either to secure satisfactory speed regulation of the unit or to avoid prohibitive pressure intensities in the turbine casing and penstock. In American practice, governor-actuated relief valves connected mechanically or hydraulically to the turbine operating cylinder and adjusted for slow-closing operation, have been exclusively used.

The author desires at this time to express the view that the differential surge tank is inherently superior to the simple tank, and that the invention of the Johnson differential tank has marked a notable improvement in the method of controlling pipe line surges. In the United States, its merits have been duly appreciated, and it is indeed surprising that this type of surge tank has not been more generally adopted elsewhere.

The great difficulties experienced with gate valves in penstocks in earlier practice have resulted in their general abandonment for this purpose; and the use of butterfly valves has been to a great extent limited to low or moderate heads and small sizes. The Johnson valve is admirably adapted to all sizes and heads, since all its sections are of circular form, giving maximum strength and freedom from distortion with minimum amount of metal. The means of effecting closure through the operation of the plunger insures freedom from rapid wear and provides a tightness of closure unapproached in any other valve.

Another application of the Johnson valve has been in power plants on streams where, due to government regulation or water rights or the requirements of plants downstream, a certain definite volume of flow must be maintained at all times. In order to effect this, the Johnson valve is used in connection with the turbine governor and is operated as an approximately synchronous bypass, so that should the flow be cut off from the turbine, the valve opens a corresponding amount and the necessary flow is thus maintained.

One of the great difficulties encountered in the operation of low head plants has been the rise in tail water with consequent reduction of head during the flood season. In order to compensate for this, two methods are used. The first, known as the Moody ejector turbine, makes use of the ejector action caused by an annular jet of water at high velocity entering the draft tube immediately below the runner. Two units of this type, each of 12,000 h.p. capacity, are now being constructed for the Hollinger Gold Mines, Limited, in Northern Canada.

The other method employed is the Thurlow back water suppressor. By this method the turbine is set in a high concrete barrel placed upstream from the spillway section of the dam. The excess of water discharged from the spillway creates a standing wave just beyond the end of the draft tube discharge passage, thus reducing the tail water elevation at the point of draft tube discharge. The Mitchell Dam Development of the Alabama Power Company was the first installation to utilise this new feature.

Designs are now developed along proper theoretical lines and then carefully checked for performance by tests of model turbines in the laboratory or at the Holyoke flume. In recent years the leading manufacturers have built private laboratories of their own in which the experimental work is carefully tested, but the Holyoke flume still serves, in a measure, as the basis of direct comparison with the earlier stages of development. An important element in the carrying out of new designs has been the practice of making field tests on completed installations, thus giving the manufacturers frequent opportunities of checking their experimental work with the actual operation of full-sized units.

It may be noted that the efficiency curve of the 55,000 h.p. unit No. 5 of the Queenston Station of the Hydro-Electric Power Commission of Ontario, which was built by the I. P. Morris Department of the Cramp Company, and was tested by the Gibson method, shows the highest average efficiency throughout the full operating range of power ever secured in a hydraulic unit. A maximum efficiency of 93.3 per cent. was attained, and for a range of output from 45,000 h.p. to 55,000 h.p., an efficiency of 93 per cent. or over was maintained; an efficiency of 92 per cent. or over was maintained from 39,000 to 59,000 h.p.; an efficiency of 91 per cent. or over from 34,500 to 62,000 h.p.; while from 31,500 to 63,000 h.p. an efficiency of 90 per cent. or more was secured.

ICE TROUBLES IN NORWEGIAN WATER-POWER PLANTS.*

By ARVID RUTHS (Director, A/S. Hafslund and A/S. Vamma).

THE cooling of the water in a lake commences at the surface level in immediate contact with the cold air, and the water thus cooled will sink to the bottom, causing the warmer water from the bottom to ascend to the surface, whence after cooling it again descends. This circulation continues until all the water of the basin in question has obtained a temperature of 4 deg. C. (39·2 deg. F.). On continued cooling the cold water will remain in the upper strata and its temperature will decrease to 0 deg. C. (32 deg. F.). Formation of ice in flowing water is governed by the same physical laws as for still water, but, in addition, also by the influence of the current. Owing to the more or less whirling motion of the water, the cooled water particles will be carried into deeper strata, even right down to the bottom. During the time when a certain particle of water is carried along the surface the cooling is so intense that its conversion into ice crystals commences. Such ice crystals, or ice needles, are also formed in waterfalls, or rapids where the water is beaten into foam.

These needles have usually a length of about 20 mm. ($\frac{3}{4}$ in.) and a thickness averaging about 1 to 2 mm. (0·04 in. to 0·08 in.). Under certain conditions, favourable to their formation, they appear in such large quantities as to fill the entire river bed from bottom to surface. The ice needles are formed in rivers where the current prevents the formation of a continuous sheet of ice, the latter acting as a heat insulating layer against the cooling effect of the air on the water. They are formed when the water temperature sinks from + 0·06 deg. to + 0·05 deg. C. (32·11 deg. to 32·09 deg. F.) and the formation continues as long as the temperature remains at, or below, this point. In local whirls these ice needles have a tendency to clot together, and these clots will in turn mutually unite, constituting large lumps of ice needles measuring several cubic metres in volume, and float down the river (1·0 m^3 = approx. 35 cub. ft.).

This formation of ice needles and their aggregates is in America and Canada termed "frazil ice," elsewhere perhaps known as "crizzle," or "young ice." The ice needles have a tendency to adhere to, and settle on, all solid objects encountered.

With cold north wind and clear weather, frazil ice formation has been observed in the Glommen river at a temperature of a few degrees below Celsius zero (32 deg. F.), while no such formation has been observed in cloudy weather under otherwise similar conditions. With air temperatures as low as —25 deg. or —30 deg.C. (—13 deg. or — 22 deg. F.) and no wind, frazil ice will not always appear owing to the presence of a heat-insulating, moisture-saturated layer of air on top of the water, which layer will prevent the cold air from cooling the surface water to the critical temperature. Frazil ice periods may last from a few days up to eight to ten days, ceasing if the water temperature for any reason rises—for instance, when cloudy weather sets in, the cold north-wind ceases, and surface ice is formed.

Norwegian water power plants have formerly, in a large measure, had to cope with ice troubles of different kinds, so serious in certain cases as to cause complete shut-down of the plant. As the causes of these ice troubles have been more closely studied and different ways and means to obviate them have been tried, we have now arrived at the stage—at least in connection with the larger plants—that these troubles no longer jeopardise operation.

The characteristic feature of the rivers of the south-eastern part of Norway is their long stretches of swift flowing water, with plenty of rapids but no intervening lakes, followed by a stretch where one or more natural lakes are formed, after which the flow continues through another narrow passage with many rapids and falls. Owing to the swift current and the many rapids, these rivers will become ice covered rather late in the season, and their water therefore will be greatly cooled. It is always the first frost period of a winter which is accompanied by the greatest ice troubles in the form of floating ice needles, and the reason for this is that the rivers have not yet been ice covered, the cooling of the water therefore being very intense. In rivers where no regulation of the stream flow has been carried out and no power development exists all natural conditions favouring an excessive ice needle formation are present.

On the other hand, the ice troubles will diminish when developments in the rivers have been carried out. The lakes will be used as reservoirs for water storage, and their water will be drawn off during the low-water period of the winter to increase the flow of the river at that time. The water, however, is not then drawn off from the surface, but through bottom outlets. Instead of cold surface water, the deep and warm water will now be discharged down the river, resulting in an increased water temperature and less tendency to ice needle formation, since the temperature is no longer so close to the critical temperature as before.

By the development of power plants and damming a long stretch of the river, a series of minor falls and rapids are combined into one head by means of a single dam. The damming then transforms the length of river in question from a series of whirlpools and rapids into an artificial lake or forebay with comparatively quiet water, which is soon ice covered in the autumn. When all available falls have been developed, and the original rapids in a river have been transformed into a series of calms, ice covered basins, or lakes, from which the water, drawn from the bottom, is carried to the turbines, the cooling of the water will necessarily be considerably less than formerly in the original state of the river, the ice troubles being also correspondingly reduced. It is anticipated that this, in connection with regulation of the lakes, will cause the frazil ice formation to disappear entirely.

The river Glommen has undergone a typical evolution in this respect. The upper part of this watercourse consists of two rivers, the Glommen and the Laagen. The Glommen flows through the valley of Osterdalen, where it forms no lake in a distance of more than 200 miles. The Laagen flows through another valley, Gudbrandsdalen, also without forming a single lake in a distance of about 200 miles, until it runs into the large and deep lake of Mjösen, the confluence of the two rivers taking place a short distance below the lake. The river then flows into another great lake, the Oieren. The total fall of the river from Oieren to the sea is approximately 100 m. (328 ft.), in a distance of 60 km. (37 miles). Of this 100 m. head, some 75 m. (246 ft.) are concentrated in a distance of about 20 km. (12 miles), which stretch, in the original state of the river, was one long, continuous rapid. Also above the Oieren there were falls and whirlpools. The natural conditions of this river, therefore, were as unfavourable as possible with regard to ice troubles. There were originally a large number of minor falls and rapids, where in winter-time the water was subjected to severe cooling. The first power plant constructed on this river —at Sarpsfossen in 1898—had therefore to contend with much ice trouble, especially heavy formation of frazil ice, at times of such magnitude as to cause complete shut-down of the plant. Gradually, however, more water power has been developed along the river; the lake of Mjösen has been dammed for storage purposes, the lake of Oieren will soon be, and, in course of the next few years, all the mountain lakes, which form the head waters of this river, will also be utilised for storage purposes. Practically all rapids from the lake of Mjösen to the sea will in the course of a few years entirely disappear, giving place to large water power developments. Surface ice will now quickly cover the calm river and protect the water against excessive cooling from the air, and the tapping of lakes and forebays will no longer be effected by drawing off the cold surface water, but the warm water from lower strata.

The evolution as outlined is typical of the majority of the large Norwegian water-courses. It is the first water power developments in a river which have to fight the ice troubles. As the water power is more extensively developed these troubles will disappear.

Again, sudden severe frost periods cause large parts of rivers to freeze up. Large quantities of water are thus converted into surface ice, ice needles, and anchor ice, as a result of which the flow will diminish appreciably. This decrease in flow varies for different rivers, depends upon the extension of the watershed, the area of water surface, and the quantity of flow. In the river Numedalslaagen with a regulated flow of about 35 m^3 sec. (1,236 cub. ft./sec.) a drop to 25 m^3 sec. (883 cub. ft./sec.) is encountered in frosty weather, in other words, 25 per cent. of the flow is retained in the river, temporarily icebound.

This phenomenon, of course, greatly reduces the output of the power stations, unless safeguarded against by increasing the discharge from the storage reservoirs as soon as the frost starts. Evidently, the power plants located immediately below the storage reservoirs are most advantageously situated in this respect. Entirely different are those plants whose water requires several days to travel from the reservoirs to the power stations as, for instance, in the river Numedalslaagen, the storage reservoirs of which are located in the upper part of the river, in the mountains, and whose power stations are close to the river outlet. The inconvenience can be overcome by running plants of this nature in parallel with power stations of the first category, which have storage reservoirs located in close proximity above, being able immediately to supply water to suit the power demand.

The same phenomenon, viz., that during its passage the water is temporarily bound in the form of ice, has

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to be taken into consideration in manipulating the discharge from storage reservoirs. If the tapping of the storage is started, *i.e.*, the stream flow is augmented, some time after a layer of surface ice has been formed, the water from the storage has to pass on top of the surface ice, since the space underneath is occupied by the natural flow existing before tapping was commenced. Consequently, in long stretches of the river, the water from the storage under these unfavourable conditions is converted into ice which will not melt until springtime. To prevent this disadvantage, the tapping of such storage reservoirs has to be started in the autumn, before the frost commences, and it must be so continued that the flow in the river below is kept as uniform as possible.

In Norwegian power plants it is particularly drift-ice and frazil-ice formation which cause trouble, and each of these requires special measures for its obviation.

Drift-ice appears when the surface ice of the river is broken up by a heavy storm, by variations in the water level, &c. In designing a plant due regard, as stated, must be given to drift-ice conditions, either by adopting an arrangement that will exclude the drift-ice from entering the forebay, or, if this is not possible, by providing such design of the forebay as will facilitate easy and quick removal of drift-ice entering.

At Vamma, on the Glommen, a new lake has been formed in the river, serving as forebay and storage reservoir for the plant. Early in the autumn, this becomes covered with surface ice clear down to the screens. This surface ice prevents drift-ice from reaching the screens, and also successfully obviates frazil-ice troubles, as any floating frazil-ice entering the comparatively still water of the forebay will get a chance to rise and stick to the ice cover before the screens are reached. At the Kykkelsrud hydro-electric plant, also situated on the Glommen, there is a long head race canal, which conveys the water from the river bed to the forebay at the power-house. The water-velocity in the canal—exceeding 2 metres/sec. (6·5 ft./sec.)—is great enough to prevent formation of surface ice, and as the entire flow of the river passes through the canal, all drift-ice, frazil-ice, as well as solid ice, will be carried directly into the forebay. Here an ice-sluice is provided which, when opened, will create a surface current alongside the screens by means of which the solid drift-ice is removed with comparative ease from the forebay.

But only surface ice can be removed in this way; drifting frazil-ice is not so easy to deal with. It has been mentioned that the frazil-ice, at times, can fill the entire river bed from bottom to surface, and that it has a tendency to stick to all hindrances encountered. The head races, for instance at Kykkelsrud, are, as a rule, shallower than the river bed, and large quantities of frazil-ice have been known to accumulate at the canal intake. An ice-barrier has been built up in front of the canal intake from bottom to surface, about 20 metres (65 ft.) wide. By careful use of dynamite, such ice masses can be blasted to pieces and the current will then carry them through the canal down to the screens. Plants of the Vamma type, without head race canal, are therefore immensely more favourable with regard to ice troubles than those with head races. At plants of the latter type, having no large ice-covered forebay as protection against ice troubles, it has been sought to remedy this disadvantage by placing, in the autumn, a coarse network of timber in the canal and river above, which by its quieting and damping action on the water will facilitate the formation of a protecting sheet of surface ice.

All ice troubles concentrate at the screens. When the ice needles strike the iron bars of the screens, they will stick to these, accumulating rapidly until the screens are choked up entirely. The entire surface of the screens can be covered with a layer of ice up to 1 metre (3·28 ft.) thick and the water supply to the turbines stopped entirely. The screens will be subjected to the full, water pressure on one side causing heavy strains on the screens and their supporting members. One case is recorded where the support gave way and the screens collapsed.

Several means have been tried to keep the screens free of frazil ice. Hand scrapers were first resorted to. As a rule these endeavours were entirely vain. Mechanical scrapers of various designs have also been tried. These were placed in fron of the screens, and consisted mainly of a frame structure, to which were fastened suitably spaced horizontal beams provided with teeth meshing with the openings between the screen bars. The frame, driven by a motor, was arranged to slide up and down the screen; but these mechanical scrapers have also proved unsuccessful.

The screens have actually to be removed when the ice troubles start and be replaced by a coarse rack of wooden planks. This arrangement allows the frazil-ice to pass through the turbines as comparatively loose masses, from which no damage will result. Large ice passing through the racks may involve a certain danger to the turbines.

With a view to keeping the screen bars above the critical temperature, heating them by steam has been tried. The bars are made hollow, with pipes conveying steam inserted into them. This method has not proved satisfactory; it is elaborate, the bars must be thicker than usual, entailing a loss in net area of the screens; the steam pipes become leaky, and the heating of the bars ceases and the freezing-up commences. Steam heating is also very uneconomical as far as the thermal efficiency is concerned, and can be considered only for plants producing steam for other purposes also. At the Borregaard power plant on the Glommen some screens are heated in this way and the steam consumption amounts to 13 kg. (29 lb.) of steam per hour per square metre (10·8 sq. ft.) net screen area (minimum water area).

The best remedy hitherto devised for protection of the screens against frazil is electrical heating of the bars. By this method, either single bars, or groups of bars, are connected in series. The current then passes through all the series connected bars, or groups of bars, and heats them. For common screens with a water velocity from 0·4 to 0·7 m./sec. (1·3 to 2·3 ft./sec.) and a bar section of about 400 to 700 mm² (0·6 to 1·0 sq. in.), sufficient heating of the bars will be obtained with 250 to 300 amperes per bar, A.C. 50 cycles.

Particulars of Electrically-Heated Screens.	Hafslund, I.	Hafslund, II.	Kykkelsrud.	Övre Lerfoss.		Nedre Lerfoss.	
				Old Plant.	New Plant.	Old Plant.	New Plant.
Number of bars connected in parallel	4	4	4	1	1	1	1
Power factor (measured at the primary side of the transformer)	0·73	0·72	0·76	—	—	—	—
Power factor (measured at the secondary side of the transformers)	—	—	—	0·88—0·87	0·85—0·86	0·85	0·86
The coefficient K	8·4	8·1	8·7	6·66	5·45	5·2	5·27
Current per bar, in amperes	270	274	275	280	240	178	290
Sectional area of bar, in mm.²	10×70	10×70	10×70	6×65	6×65	6×65	6×65
Current density per bar, in amp./mm.²	0·39	0·39	0·39	0·72	0·615	0·455	0·75
Frequency (at the test)	50	50	50	48	48	48	48
Voltage between outer phases	225	225	215	156	158	164	162
Method of bar field connection	Y	Y	Δ	Δ	Δ	Δ	Y
Free opening between bars, mm.	32	32	28	46	36	25	32
Water velocity through screen, metres/sec.	0·6	0·49	0·65	0·65	0·79	0·514	0·78
Energy consumed per m³ flow of water, kw.	5	5·7	5·2	6·9	4·8	3·5	4·8
Energy consumed per m² effective screen area, kw.	3·1	2·8	3·3	4·5	3·8	1·82	3·76
Length of bar per m³ water consumption in m.	52	64	54	56·5	60	86·5	45
Energy consumption per linear metre bar length, kw.	0·095	0·09	0·094	0·12	0·081	0·041	0·106
Energy consumption per m² of bar surface, kw.	0·6	0·56	0·58	0·85	0·566	0·29	0·75

At Kykkelsrud, water is admitted to each of the 6,000-h.p. turbines through a screen of three panels. The length of the screen bars in this case is 8,650 mm. (28 ft. 4 in.) and each panel contains 56 bars of 70 × 10 mm. (2¾ in. × ⅜ in.) section, parallel-connected in groups, comprising four bars each. This connection is made by a suitable piece of channel steel, welded to the ends of the bars. The bars are fastened to a frame of oak, which again is bolted to a steel frame resting against the supporting structures of the dam. Oak has been used for insulation.

The calculation of the power consumption is based on the ohmic resistance of the screens. Assuming the specific resistance of steel to be 0·1, the theoretical resistance of a screen comprising four bars, of the dimensions stated above, is:—

$$R_1 = \frac{0{\cdot}1 \times 8{\cdot}65}{700} \times \frac{1}{4} \times \frac{53}{4} \times 4 = 0{\cdot}0173 \text{ ohm.}$$

The actual resistance, however, is considerably greater owing to the additional resistance of the welded bar connections, the cables, &c., and has been measured for the field in question at Kykkelsrud as:

$$R_2 = 0{\cdot}15 \text{ ohm} = K R_1 = 8{\cdot}7 R_1$$

The screens at Kykkelsrud work with a power factor ($\cos \phi$) = 0·76. With above values of the coefficient K and the power factor it is an easy matter to compute the power, voltage, and transformer capacity required to obtain a current of 250 to 300 amperes through the screen bars.

The table on this page contains particulars and readings from various electrically-heated screens, the values given for power consumption, &c., being those found adequate to prevent the ice needles from adhering to the bars.

As will be seen in the table, the power consumption of these screens averages 5 to 6 kw. per cubic metre of water passing through the screens per second.

Solid ice blocks settling at the screens must be removed by the watchmen as quickly as possible. Manual assistance cannot, therefore, be entirely dispensed with by the use of electrically-heated screens, but while formerly—with unheated screens—a gang of fifty to sixty men, working with scrapers on the screens, failed to maintain the operation of the plant, it is possible, with heated screens, to keep the same plant going during the worst periods of frazil-ice formation by the aid of a few men only, for removal of drifting ice blocks.

Plants having uncovered pipelines between the dam and the turbines are troubled in frosty weather with interior icing of the pipes, the inside of these being covered with a compact layer of solid ice up to 30 cm. (12 in.) thick in certain cases. As, with increasing water and air temperatures, the ice cover becomes loosened on the inside of the pipe, hard, solid pieces of ice will be carried down to the turbines where they may cause damage and interruption of the service. This trouble can be overcome by protecting the pipeline against the influence of the cold air, either by imbedding it in concrete, or by covering it with some heat-insulating material.

Ice sluices and various other discharge openings are liable to clog up with ice, and must be kept open by steadily cutting the ice away. Such icing is prevented by inserting electrical heating elements in the adjacent masonry, such elements to be of about 1,000 watts capacity, spaced about 1½ to 2 metres (5 to 6½ ft.) apart. In this way the masonry is heated sufficiently to exclude the possibility of ice growth, facilitating clean discharge passages during the most severe frosts.

The same preventive, *i.e.*, imbedded heating elements, can also be used as a guard against roller dams freezing up to the side walls at both ends of the roller. Equal results are also obtained by provision of suitably located, electrically heated steel bars. The latter method is employed at the Vamma power plant to protect the roller dam against freezing.

In connection with paddle or needle weirs, a certain condition may arise which is worthy of attention. When the river above the weir freezes up, the ice cover will extend right down to the needles and freeze on to these. If now the water level above the weir varies it may happen that the needles may be lifted over the sill of the weir and carried away, great quantities of water being then suddenly discharged. To avoid this calamity it is of the utmost importance at all levels of the water to keep an open lane in the ice, about 1 metre (3·28 ft.) wide, in front of such weirs.

THORNYCROFTS IN CANADA.—Following a visit to Canada last year by a representative of Messrs. John I. Thornycroft and Co., Limited, the company opened a depot at Toronto, and they have now established another at Montreal for the sale of their productions. A number of Thornycroft motor vehicles is already in service in Canada, including several owned by Messrs. The T. Eaton Company, who are the largest store owners in the Dominion, and these Canadian depots will provide service facilities and be used for the stocking and assembly after shipment of Thornycroft chassis and marine engines. Messrs. Thornycroft are also established at Calcutta, Cairo, Copenhagen, Singapore, Shanghai, Rio de Janeiro, Buenos Aires, Sydney and Melbourne, each organisation being under the direction of one of their own trained staff.

SISAL HEMP PRODUCTION IN THE EMPIRE.—Sisal hemp is chiefly produced in Mexico, where the annual output is about 150,000 tons. More than nine-tenths of this goes to the United States, where it is employed for the manufacture of the binder twine used in harvesting machines, the demand for binder twine for this purpose amounting to about 200 million lb. annually. It is obvious, therefore, that European buyers must look to countries other than Mexico for adequate supplies of the fibre. An abstract of the present position of sisal hemp cultivation in the British Empire is given in the Bulletin of the Imperial Institute. East African sisal, produced in Tanganyika and Kenya Colony, is of excellent quality, and large quantities come to this country, where it realises prices higher than those of Mexican sisal. The Bahamas also grow the fibre on a fairly extensive scale, but the whole of their output is taken by the United States. No other country in the Empire is at present producing large quantities of the fibre, but commercial supplies may be expected in the near future from Ceylon, Nyasaland, Gold Coast, Mauritius and Jamaica. Several other regions are well adapted to the crop, and have extensive areas available for its cultivation.

THE RECIPROCAL UTILISATION OF WASTE ENERGY.*

By BERNHARD MORITZ GERBEL.

The most favourable conditions for the utilisation of waste steam are, of course, found only in the special cases where the different sections of a plant require just as much waste steam as is supplied in this plant by the steam engine. If the quantity of waste steam required is greater than the quantity supplied, we must add live steam; if the quantity required for boiling and heating purposes is smaller, we must choose steam engines working with extraction of steam from the receiver, or bleeder turbines.

The reason why the utilisation of waste heat in steam plants has, up till now, not assumed larger dimensions, is that the leaders of large industries, the managers and the other competent persons are interested only in the progress of heat technics as far as their own plant is concerned. The utilisation of waste heat beyond their own plant is generally not thought of, whereas the possibility of developing the utilisation of waste heat is founded especially on its employment outside their own plant, a combination which would be extremely economical for the various plants and of greatest importance for political economy.

The future development of the utilisation of waste heat does, therefore, not only depend on the combination of the generation of power with the employment of waste heat for boiling and other purposes within the reach of one and the same plant, but on the co-operation of different plants for the purpose of the utmost joint utilisation of their fuel.

The above deals with waste energy in the form of waste heat; waste energy is also available in the form of waste power in steam plants. Steam of higher pressure can be generated with nearly the same quantity of fuel as steam of lower pressure, as there are 647 calories in 1 kg. steam of 2 kg. atmospheric pressure, while, for example, steam of 14 atmospheres and 300 deg. C. contains not more than 729 calories. The amount of calories contained in the second case is therefore only 13 per cent. larger, and the quantity of fuel required in both cases is approximately in the same proportion. In large plants requiring great quantities of low-pressure steam for manufacturing purposes we can, therefore, instead of low-pressure steam, generate without great cost high-pressure steam and utilise the higher pressure of this steam in back-pressure engines for the generation of power, where the steam leaving these engines will still have the pressure required for the said purposes. In this case we obtain a certain quantity of very cheap power which we are entitled to call "waste power."

Plants requiring about 6–16 times as much steam as horse-power hours for manufacturing purposes, can themselves consume the whole or most of their waste energy. In this respect such plants offer the highest efficiency. But these cases are rare; in most industrial branches we find a different proportion between the steam and the horse-power hours required and, therefore, most of the plants could feed other plants with either waste heat or waste power in great quantities. The price of these waste energies could, of course, be very low, and the sale of this energy could be all the more profitable the more the proportion mentioned differs from the figures given above, *i.e.*, 6–16. If the proportion is below the figures mentioned, the plants can supply heat-(waste steam), in the other case power can be supplied.

The annexed table attempts to classify different industries according to this point of view. The different branches are divided into three main groups, the first of which contains industries consuming power without, or almost without, requiring heat for manufacturing purposes. The power required per unit of production—shown in column 3—is quoted in column 4, and the steam required for manufacturing purposes is stated in column 5, both referring to the unit of the finished product.

The industries of the first group require almost no steam for manufacturing purposes, their characteristic figure is 0 or nearly 0; that means that, if they are driven by steam power, they dispose of waste energy in the form of waste steam. The quantity of this heat is given in column 7 and amounts to 2,400 to 11,000 calories per horse-power hour, according to the temperature and the pressure of the exhaust steam.

In the second and third groups there are branches requiring power and steam for manufacturing purposes, the columns being as for the first group. The figures quoted are to be understood as the highest and lowest limit, for the characteristic figures; moreover, an average is quoted, according to which the classification has been made. The characteristic figures of the second group lie between 6 and 16; there remains, therefore, neither waste heat nor waste power.

The third group shows characteristic figures above 16; that means that these industries require a comparatively large quantity of steam for manufacturing purposes per horse-power hour required. The average characteristic figures are between 20 and nearly infinity. In these plants the quantity of steam required for manufacturing purposes is very large in comparison with the power required. Even if the power required is in such cases generated in back-pressure engines and the whole waste steam is fully utilised, there is still a large quantity of steam necessary in these industries, which must be drawn directly from the steam boilers. The industries working in this manner are quite up to date in respect of their technical heat apparatus; they fully utilise their waste heat, and the useful effect, attained by employing the added live steam, can be made nearly 100 per cent. Nevertheless, the added live steam is not utilised so well as would be the case if it were first to pass also through an engine in order to generate power and to be utilised afterwards, at lower pressure, as waste steam. In this case the result would be a certain amount of very cheap disposable power.

Another combination is, for similar reasons, the joint work of spinning mills with weaving mills, dyer's works, print works, &c. Spinning mills require hardly any steam, but chiefly power (group 1), while dyer's works require large quantities of steam (group 3). Weaving mills (group 2) do in many cases consume the whole of their energy, but if they also dress their products they require a great deal of steam and therefore dispose of waste power. These industries are also often found situated close together, therefore the mutual utilisation of heat and power would save them a great deal of fuel.

If there are no other common interests, such as those mentioned above, between plants of the first and third group, a combination will nevertheless be of great advantage if the costs of the coal required form an important item in the expenses of these plants. Such plants are, for instance, on the one hand, steam power electric stations, on the other hand, heating and bath plants. The waste heat of an electric station can easily be utilised for the heating of a large district of a town

ENERGY REQUIRED AND WASTE-ENERGY OF DIFFERENT BRANCHES OF INDUSTRY.

No.	Branch of Industry. (Type of Plant.)	Unit of production referred to.	Energy required. Power required quoted in H.P. hours.	Energy required. Steam required for manufact. purposes.	Characteristic figure. (proportion of col. 5 to col. 4).	Waste energy.
1	2	3	4	5	6	7
	Group 1: Industries disposing of waste heat. Electro-chemical industries.					
1	Aluminium	1 kg.	35	—	0	Where these industries are driven by steam power, the results are according to the type of engine employed per horse-power hour: 2,400 cal. in form of 4 kg. vacuum steam or 50 kg. condensed water of 70° C.; 3,800 cal. in form of steam of 1 atm.; 5,000 cal. in form of steam of 7 atm.; 7,800 cal. in form of steam of 11·5 atm., &c.
2	Air-nitre (saltpetre)	1 kg.	11	nearly 0	nearly 0	
3	Hydrogen	1 cbm.	11	„ 0	„ 0	
4	Lime-nitrogen	1 kg.	5	„ 0	„ 0	
5	Calcium carbide	1 kg.	5	„ 0	„ 0	
	Other industries:					
6	Oxygen (air-distill.)	1 cbm.	4	nearly 0	nearly 0	
7	Wood pulp (mechanical)	1 kg.	2	„ 0	„ 0	
8	Spinning mills	1 kg.	2	„ 0	„ 0	
9	Electricity	1 Kwh.	1·5	„ 0	„ 0	
10	Rolled iron	1 kg.	0·16	„ 0	„ 0	
11	Cement	1 kg.	0·13	„ 0	„ 0	
12	Wheat mills	1 kg.	0·1	„ 0	„ 0	
13	Ice	1 kg.	0·05	„ 0	„ 0	
	Group 2: Industries not disposing of remarkable quantities of waste energy.					
14	Beer	1 litre	0·1—0·2	0·5—0·9	3— 6— 9	The waste energy (exhaust steam) resulting from the generation of power is entirely or nearly entirely consumed for own manufacturing purposes.
15	Potato starch	1 kg.	0·1—0·2	0·1—1	3— 6—10	
16	Paper	1 kg.	0·4—0·6	2·5—3	4— 6— 7	
17	Weaving mills	1 kg.	1 —1·5	8 —12	5— 8—12	
18	Cellulose	1 kg.	0·4—0·5	5·5—6·5	11—13—16	
19	Leather	1 kg.	1 —1·3	15 —22	12—16—22	
	Group 3: Industries disposing of waste power.					
20	Artificial silk	1 kg.	6—8	110—150	14—20—25	Per 1 kg. steam required for manufacturing ⅓—½ h.p. hour can be obtained; there remains therefore, a considerable quantity of free power to be disposed of.
21	Press yeast	1 kg.	0·6—1	16—22	16—25—40	
22	Matches	10,000 boxes	30—35	700—1100	20—27—37	
23	Sugar	1 kg.	0·15—0·25	5—6	20—30—40	
24	Laundries	1 kg.	0·3—0·4	9—11	22—30—37	
25	Glue	1 kg.	0·7—0·9	25—35	28—40—50	
26	Potato syrup	1 kg.	0·05—0·07	2—2·8	30—45—56	
27	Dyer's works	1 kg.	0·05—0·1	3—5	30—65—100	
28	Distilleries	1 litre	0·1—0·2	6—15	30—70—150	
29	Soap	1 kg.	0·1—0·2	6—18	30—80—180	
30	Bathing plants	1 compl. bath	0·3—0·5	40—70	80—100—230	
31	Central heating station	1 cu.m. air/hr.	0	0·02—0·04	nearly infinity	

The costs of installation to make this possible are reduced to the small increase on the costs of a larger engine, as the size of the boilers is not altered by this. By means of such utilisation of the steam pressure it is, in this group, possible also to generate very cheap electric current in steam plants, and these sources of energy are far more productive than people generally think.

As regards the groups of industry in the table, we at once see the advantages offered by joining some branches of the first group to some of the third, in order to utilise mutually their waste energies. The first group only requires power which the third group leaves unused, and this waste-power of the third group can be supplied far cheaper than the power generated in the plants of the first group. The possibilities of such local combinations are numerous, and they would be still more advantageous in cases where the industries have also other common interests besides the intention of joint utilisation of energy.

For instance the distilleries and the manufactories of press yeast, industries of the third group, are closely related to mills, an industry of the first group, and often these two kinds of industries are situated near one another. But in spite of such favourable juxtaposition we generally find in both of these plants, a steam generator as well as a power station, the distillery is provided with great boilers, whereas the mill is generating the power required out of coal, without utilising its waste-heat. A common steam generator and power station would save both plants nearly 70-80 per cent. of the coal required for the mill.

to which it is also supplying electric current. In some cases arrangements have already been made to conduct the warm water, heated by the vacuum waste steam of the electric station, through the heating pipes of the houses in the neighbourhood, and to sell the heat under similar conditions as the electric current. The inhabitants of such houses get their bills for heating like those for electric current. Of course the heating with this waste heat generated at such small cost can be supplied far cheaper than by special heating plants.

To realise such ideas the engineer must comply with two conditions limiting the local extension of such establishments. First, the possibility of accumulating heat without great losses must exist, for the requirements of heat for heating purposes are the largest in the morning, the requirements of current most in the evening. Therefore the waste heat obtained in the evening has to be stored for the next morning. That can be done, for instance, in the large warm water reservoirs, the contents of which are heated in the evening by waste steam. If the insulation of such reservoirs is well executed, the loss of heat is very small and the whole heat is available in the morning. The quantities of warm water required and the size of the reservoirs assume in these cases large dimensions and form, therefore, a limit for the extension of such establishments.

The second condition is the existence of the possibility of conducting heat to distant places without considerable loss. The development of insulation has brought about already great progress in this respect. It is possible to conduct the heat, with profit, over distances of 3 km. and more. This shows us a new

* Paper, abridged, contributed to Section D of the World Power Conference on July 3, 1924.

line of development for electric stations. The economical importance of utilising the waste heat of these stations for long distance heating purposes requires a division of them into smaller plants, the size of which is limited by the districts to be provided with waste heat.

There are, however, great difficulties in the combination of plants requiring power, with others disposing of waste power. The quantity of power required, in most cases, varies considerably at every moment, as does the disposable waste power, but in such cases not in the same direction. Therefore it will be advantageous to utilise the waste power of the plants in question for supplying current to a common electric network, which then feeds all plants requiring power with electric current. The existing electric stations could considerably reduce their costs of generation by inducing all industries disposing of waste power and situated within the reach of their network, to help to feed this network with current. The electro-technical problem of making possible the feeding of various current suppliers in a common network without danger for the central station, can be solved in most special cases, so that, in this respect, no objection could be made. For instance the Vienna electric central station already collects waste energy of different industrial plants in its network and schemes of extending this procedure are in hand. For the present this central station, however, collects waste power only from power central stations, and does not use the waste power of steam or heat-consuming industries and plants. This can, however, only be considered as a first step.

RECENT SWEDISH ARCH DAM DESIGN.*

By Bo HELLSTRÖM, Vattenbyggnadsbyran, Stockholm, Sweden.

IN the design of arch dams the question as to what extent stresses resulting from changes in temperature and from the shrinkage of the concrete should be taken into account, has been the subject of different opinions. Existing non-reinforced single arch dams show considerable cracks, which evidently must be caused by stresses of this kind, as may be gathered, for instance, from an investigation of arch dams in Australia. Although old Swedish arch dams, as those at Gullspång and Stenkvill-Klints, which are slightly reinforced only, have been well maintained, the Swedish arch dams of recent date have been strongly reinforced. Among these dams there are the single-arch dam at Gideåbacka and the multiple-arch dams at Suorva and Melby. The Suorva dam has been designed and constructed by the Royal Board of Swedish Waterfalls, the other two were designed by the Vattenbyggnadsbyrån (Consulting Hydraulic Engineers of Stockholm). In the following, a short account of these dams and of the principles of their design will be given.

In the calculations, attention has been paid to the horizontal arch effect as well as to the vertical cantilever effect, due to the dam's support at the bottom.

In the design of the Gideåbacka dam it was necessary to take into account variations of the temperature of the air from + 25 deg. to −25 deg. C. (+ 77 deg. to − 13 deg. F.) and of the water from + 15 deg. to 0 deg. C. (+ 59 deg. to + 32 deg. F.). Lacking exact knowledge of the extreme temperature curves for a section through the dam, it was assumed that these be represented by straight lines. From a recent investigation of this matter it is, however, evident that the extreme temperature of the concrete follows a sharply bent curve.

In calculating the bending moments and the normal pressures, there is some uncertainty as to the modulus of elasticity of the concrete, which, as is well known, varies considerably. Different values of the bending moment and of the normal pressures, resulting from temperature and shrinkage, or from the water pressure, will be obtained, depending on whether a solid or a two-hinged arch be considered. In the first case the moments will be much bigger than in the latter. The bending moment at the abutments is particularly big in the solid arch. It was on this account that the Gideåbacka dam, on its upstream side close to the abutments, was provided with joints and hinges, with a view to making the dam act more as a two-hinged than as a solid arch.

The stresses resulting from the shrinkage of the concrete are equal to the stresses caused by a sinking of the temperature of 5 to 10 deg. C. (9 deg. to 18 deg. F.). The shrinkage stresses can be reduced by casting the concrete in separate sections, but so far this method has not been adopted in Sweden owing to the particular difficulties involved with regard to the reinforcement.

It is apparently becoming a general opinion that arch dams just as well as arch bridges should be designed according to the theory of elasticity in relation to temperature and shrinkage. In this connection, attention is called to the fact that the reinforcing steel in a dam, provided that the centre angle and the thickness of the arch are given, does not in the least reduce the stresses resulting from temperature and shrinkage. The reinforcement serves to prevent the formation of large cracks, which may threaten the stability of the dam. Should cracks occur these will be very small and evenly distributed and therefore less dangerous. The main object of the reinforcement, however, is to make it possible to reduce the thickness of the arch and thereby its rigidity, as, by making the arch less rigid, the stresses resulting from temperature and shrinkage will be reduced.

In Sweden the discharge over the dam must often pass through flood openings along the crest. The water-pressure against the gates is then being transmitted, through thin piers, to the arch. In cases where some of the gates are opened and some shut, the arch will be exposed to an unevenly distributed pressure, to which special attention has to be paid.

If the up-stream side of the arch dam is inclined, the water pressure against the arches increases towards the abutments. Naturally, this must also be taken into account. In the design of inclined arches the weight of the structure must also be considered, as this causes considerable stresses. Owing to the transverse expansion of the concrete, attention should be paid even in vertical arch dams to the weight, although it has but a secondary influence upon the arch stresses. In very high dams this is of special importance for the lower parts of the dam. The resulting deflection against the upstream side reduces, however, the stresses from the water pressure.

In the severe climate of Northern Sweden the surface, even of flowing water, is often frozen, and due regard must be paid to the pressure that the ice may exert against the dam.

As the arches are fixed in solid rock at the bottom, there will be bending stresses in a vertical direction neutralising the arch effect at the bottom and, to some extent, even higher up in the dam. Owing to this, the dam reacts against the load by both arch and cantilever effect.

The Gideåbacka dam has a span of 40 m. (131 ft.) and a maximum height of about 26 m. (85 ft.). The radius of curvature of the up-stream side changes from 30 m. (98 ft.) at the crest to 22 m. (72 ft.) at an elevation 13 m. (43 ft.) lower down. Below this elevation the radius is constant. In addition to the above-mentioned flood openings at the crest, the dam has two bottom outlets, closed by stop logs, which were used during the period of construction. These outlets can be opened by pulling up or by blowing up the stop logs, in case the reservoir formed by the dam needs to be emptied. The thickness of the arch is 2 m. (6 ft. 7in.) at the crest and about 5 m. (16 ft. 5 in.) at the bottom.

The concrete was made with the mixture 1 : 3 : 4, except nearest to the surface, where 1 : 2 : 2 was used. Near the upstream surface a row of vertical drain pipes have been arranged, connected at their lower ends to an outlet and at the tops left free to the air in order to avoid vacuum in the pipes. The dam is strongly reinforced. The reinforcing steel is arranged mainly in a horizontal direction. The area of the steel amounts to at most 142 sq. cm. per metre of height (6·7 sq. in. per foot) at the upstream as well as at the downstream side.

The Suorva dams,* designed according to the multiple-arch system, are erected across two branches of the Lule River, in Lapland. The dams are located at about 67·5 deg. north latitude, in a district where the winter temperature is sometimes as low as — 40 deg. to — 60 deg. C. (40 deg. to 76 deg. F. below zero). The maximum height from the bottom to the crest of the dams in the present stage is 14 m. (46 ft.). At a future development this height will be increased by 7 m. (23 ft.). The distance between the centres of the piers is 12 m. (38 ft.). The inclination of the arches is 45 deg. to the horizontal. The curve of the arches—taken at right angles to the inclination is composed of three arcs.

The thickness of the arches varies from 0·8 m. (2 ft. 7 in.) at the crest to 1·7 (5 ft. 7 in.) at the bottom. In order to attain sufficient rigidity in a lateral direction, the piers are provided with special reinforcement at the downstream side. At the upstream side tension members connect the piers, in order to react against the thrust from the arches during construction, and also with a view to preventing a disastrous calamity should a partial break-through occur on account of some damage wilfully done to the dam.

With regard to the extreme severity of the climate in this part of the country, the arches are strongly reinforced in the direction of the generatrix, as well as at right angles to that direction. The mixture of the concrete in the arches is 1 : 2·5 : 3 and in the intermediate piers about 1 : 5 : 6·5. On account of the difficulty of supplying sand in sufficient quantities at a reasonable cost, sand obtained by crushing the rock has been used as a substitute. In the arches, however, such sand has been used to a limited extent only, about 25 to 40 per cent. of the sand in these parts being natural sand, in order to facilitate the working of the concrete. On the upstream side the arches are provided with two 10 mm. (⅜ in.) coatings (mixture 1 : 3), applied by means of cement guns.

In order to avoid excessive changes of temperature in the lowest parts of the arches, which are the most sensitive to such influence, the downstream side has been protected up to 2·5 metres (8 ft.) from the ground by a stone and earth fill, with a small open space left nearest to the arches.

The Melby dam is 78 metres (256 ft.) long and 8 metres (26 ft.) high. The inclination of the arches is 2 : 1 or 63·5 deg. to the horizontal, and the arches are strongly reinforced. There are no tension members in this dam. An intake for the penstock in the middle of the dam divides the dam into two independent parts. As a protection against great changes of temperature at the bottom, where the arches abut against rock, an earth fill has been arranged along the downstream side.

At the Gullspång dam, one of the earlier arch dams in Sweden, interesting reinforcement work has recently been carried out, and it may be justifiable to give here a short account of this work. At the time of construction the weather was very unfavourable, and therefore some parts of the concrete in the arch did not turn out to be first class work. As a result, some leakage appeared in the dam, and in some parts of the concrete the cement has been gradually washed out during the last thirteen years. Last year tightening work on the upstream side was carried out in the following way: A form, provided on the inside with a coat of callendrite—a kind of asphalt sheeting—was erected on the upstream side 8 to 12 centimetres (3 to 5 in.) from the surface of the dam. The space between this form and the dam was then filled, under water, with 1 : 1 cement mortar through pipes reaching below the level of the water. A considerable portion of the mortar found its way to voids and cavities in the old concrete, as could be ascertained from the fact that a far bigger amount of mortar was required than the quantity corresponding to the volume between the dam and the form, and that no mortar leaked out through the form. The dam was thus made absolutely tight. It is now intended to erect a reinforced facing, 20 centimetres (8 in.) thick, covering and protecting the downstream side of the dam. In order to secure a close adherence to the old concrete, this facing is to be made in exactly the same way. The form used for the concreting will be retained as a protection against the cold.

This method of applying a coat of concrete to an old dam in the above manner has proved very successful, and the author believes that in this way many old arch dams affected by leakage and cracks may be provided not only with a suitable layer of reinforcing steel but also with a very hard and resistent facing, at a relatively small expense, and without any interruption of the operation of the water power plants.

* Paper, abridged, contributed to Section B of the World Power Conference on July 4, 1924.

* These dams were fully described and illustrated in ENGINEERING, vol. cxvi, pp. 731 *et seq.*—ED. E.

CORROSION.—A very comprehensive report on corrosion of iron and steel, with special reference to cast-iron has been prepared by The British Electrical and Allied Industries Research Association, 19, Tothill-street, Westminster, S.W.1. It is a complete compendium on the subject, covering the manifestations of corrosion; the action of sea-water; the effect of velocity of water on corrosion; the effect which various alloys, silicon, phosphorus, carbon, &c., have on corrodibility; the effect of treatment by protectives, such as paints, varnishes, cement, galvanising, sherardising, &c. The report will be found useful by metallurgists and by the engineering profession generally.

GUIDE TO THE BRITISH EMPIRE EXHIBITION.—We have received from Mr. Barrington Hooper, the Controller of Publicity, a copy of the new Official Guide. This was prepared by Mr. G. C. Lawrence and has many new features, while those of the older editions have been greatly improved. Many half-tone illustrations and a series of plans add greatly to the value of the publication. Hints are provided on touring the great undertaking for those with a day, three days or a week at their disposal for the purpose. The information regarding the Dominions and Colonies has been extended. This Guide is published by the Fleetway Press, Limited, of 3-9, Dane-street, High Holborn, W.C.1, at a price of one shilling.

CARDIFF AT WEMBLEY.—Cardiff will occupy the Civic Hall at the British Empire Exhibition from the 21st to the 30th inst. inclusive. The purpose is to portray the interests of the city, both from the historical point of view and from that of modern municipal enterprise, and to demonstrate to Dominion, Colonial and foreign visitors the immense facilities Cardiff has to offer as a commercial city and a great port. Cardiff exhibitors will display coal, wagon building, wire ropes, Welsh textile manufacture, driving belts, &c. The intention is to make use of this opportunity to develop new markets in the Dominions overseas, and to show that Cardiff is determined to play its part in the development of Empire trade, thus attaining one of the principal ends in view in the establishment of the British Empire Exhibition.